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PEST MANAGEMENT ALLIANCE FOR THE CONTAINERIZED NURSERY INDUSTRY

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Disclaimer

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Abstract

This pest management evaluation was developed to provide background information on pests of the containerized nursery industry in California and the management of those pests identified as major problems. In addition, the interacting economic, social, and environmental issues of pesticide regulations, newly introduced pests, and contamination of waterways by runoff are considered. Our survey of nurseries determined red imported fire ant was the primary pest concern for those nurseries located within the quarantine area for all three of these issues (regulations mandating use of pesticides, cost of these pesticides, runoff of pesticides after treatment, worker exposure due to increased use of these pesticides). Even outside of the quarantine area, growers were greatly concerned with pesticide cost, runoff, and environmental regulations. In the top 5 nursery producing counties, 27 pesticides accounted for 85% (by weight of active ingredient) of all pesticides used. Of these, 6 of the 9 insecticides in the list were carbamates or organophosphates, which are implicated as contributing to health and environmental risks due to worker exposure or impairment of the health of water bodies due to runoff in surface and ground waters. Alternative methods to reduce the use of these materials and other pesticides used in nurseries are available and can be adapted for use in ornamental production areas.

Pest Management Evaluation

A. Nursery Production

In 1997, nursery products ranked 3rd in the state among agricultural commodities with a value of $1.8 billion (CDFA,2000). California is the leading producer of nursery and greenhouse products in the United States (Economic Research Service, USDA, 1999) and is the most important nursery production state (by percent of U.S. receipts) in the U.S., producing 20% of the nursery crops followed by Florida (11%), North Carolina (8%), Texas (8%), and Ohio and Oregon (5% each) (Economic Research Service, USDA, 1999). In 1997, outdoor nurseries in California occupied 21,643 acres (Economic Research Service, USDA, 1999). The net sales value in of the crop in 1997 was $6.6 million. Aside from capital costs such as land and equipment, and buildings and costs associated with transportation of the product, production costs include labor, fertilizer and pesticides, pots, propagative material, potting mix, pots and labels. To be successful, nurseries must operate on a gross profit margin of 30% or better (California Association of Nurserymen, 1999).

B. Production Regions

Most nurseries are located on the coastal regions of California due to the mild climate. Because freezing temperatures rarely impacts these regions, plants can be produced and sold year round. Also, because there is little need to protect plants from low temperatures, most nursery stock (over 80%) is grown in containers (Schuch and Klein, 1996). The top producing counties in California in 1997 (latest data available) are San Diego, Los Angeles, Orange, San Mateo, and Ventura (CDFA, 1998).

C. Cultural Practices

Outdoor grown nursery crops are predominantly grown for sale to retail nurseries and then to consumers for landscaping. There may also be direct sales to commercial landscapers and some nurseries operate both wholesale and retail businesses. Commercial nurseries may also produce stock for commercial fruit and nut plantings. However, for the purposes of this evaluation, only outdoor grown containerized ornamental plants are covered.

Individual nurseries may produce over as many as 1000 different species of plants (Schuch and Klein, 1996) and plants are grown for sale year round. Because of the constant demand for plants, nursery products can be found in varying stages of growth in a nursery. In addition, plants are sold in different sizes depending on the customer's needs. In general, woody shrubs are sold in 1, 3, or 5-gallon containers while trees are sold in 10 or 15-gallon pots or larger boxes. Depending on the type of plant and desired size, an individual plant may be sold as soon as 1 month from transplanting to as long as 3 years. Generally, only large trees, topiary types, or very slow growing plants stay in a nursery as long for 3 years or more. Most 1-gallon plants are shipped in 1-6 months and 5-gallon plants in 2 months to 2 years. Because production is year round and there is a diversity of plants grown in each nursery, there is always a lot of human activity in the production areas, including pruning plants, moving containers, watering, applying pesticides, and scouting for pests.

Nursery crops are usually grown from liners. These are vegetatively propagated plants grown in a protected area such as a greenhouse or shade house in small (2-4") pots. Unless the species is very vigorous, liners are transplanted into 1-gallon containers. After the plant is established, it can either be sold or transplanted into progressively larger containers. Plants in larger containers are sold at higher prices to recover the additional cost of labor, materials, and time in the nursery. Containers are set on woven nursery mat to reduce the growth of weeds around the containers. Gravel may be used in place of or over the mat.

Most containerized plants are grown in either a soilless mix or one containing only a small amount of soil. Soilless potting mixes may contain peat moss, sand, sawdust, bark, compost, or other materials in varying percentages depending on how the mix is to drain and its weight. Drainage is important because there is no buffering of water amounts in the container; if the mix remains wet for too long a period, plants become more susceptible to root diseases. If it drains too quickly, the plants must be irrigated more often or else they will wilt and die. The weight of the potting mix is important because of shipping costs and because the containers are regularly moved to change spacing or fill in an area after a section is sold.

Fertilizing is accomplished by incorporating a quick release fertilizer in the potting mix prior to transplanting. This is supplemented with regular fertilization through the irrigation system or by using a slow-release top dressing of fertilizer. The slow-release fertilizer can also be incorporated into the potting mix prior to transplanting.

Plants must be irrigated to maintain good growth. One-gallon containers are irrigated using impact sprinklers and larger containers are watered using impact sprinklers, drip, or microsprinklers. In smaller nurseries and where needed in larger nurseries, irrigation is supplemented with hand-watering. Water not taken up by the plants or drained into the soil can be directed to run off into recycling ponds, into other areas that have plants that can be sub-irrigated, or off the property. While the cost of water varies in the production regions, even if water is relatively cheap, runoff is avoided because it is difficult to work in wet areas.

Pests are controlled by various methods. Weeds are hands-picked from containers prior to regular applications of preemergent herbicides. Disease control is accomplished by preventative treatments of fungicide applied as a soil drench or spray. Less often, fungicides are used as curative treatments. Generally, when a plant show symptoms of disease, it is culled and discarded. Insects are controlled primarily by insecticides and less often by pruning or other method. In 1997, nearly 156,149 pounds of pesticide (active ingredient) was used in outdoor ornamental plant production in the top five nursery production counties (CDPR 1997 Pesticide Use Reports). Twenty-seven pesticides accounted for 85% of all active ingredients by weight (Table 1).

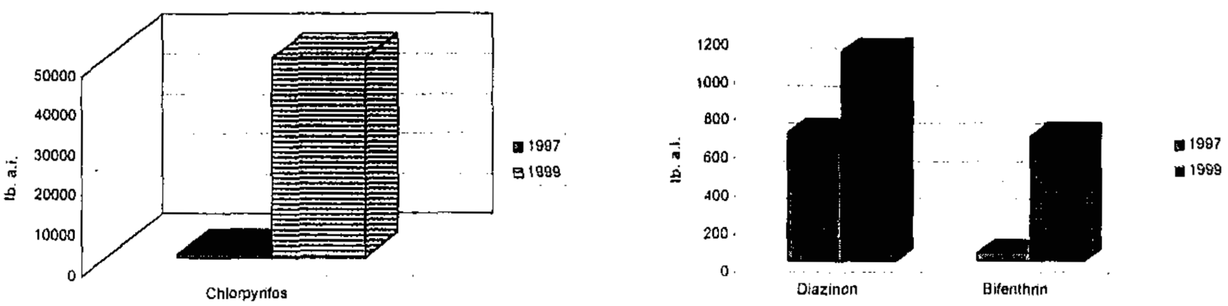
Table 1. Number of applications and pounds of active ingredient of the most heavily used pesticides[1] used for outdoor ornamental plant production (does not include cut flowers) in Los Angeles, San Diego, Ventura, San Mateo, and Orange Counties in 1997 (CDPR, 1997 Pesticide Use Reports).

Pesticide	Type	#applications	lb.a.i.
Chlorothalonil	Fungicide	613	3,516.33
Copper hydroxide	Fungicide	868	2,396.71
Fosetyl-al	Fungicide	598	7,528.11
Mancozeb	Fungicide	680	3,587.91
Metalaxyl	Fungicide	1,953	1,426.19
PCNB	Fungicide	153	2,803.71
Sulfur	Fungicide	133	3,316.67
Thiophanate-methyl	Fungicide	1,519	5,292.53
Iprodione	Fungicide	758	1,748.58
	Total fungicide		**31,616.74**
Methyl bromide	Fumigant	52	6,951.10
	Total fumigant		**6,951.10**
Diquat dibromide	Herbicide	736	3,539.05
Glyphosate, isopropylamine salt	Herbicide	3,048	18,976.59
Oryzalin	Herbicide	1,290	5,224.69
Oxyfluorfen	Herbicide	403	3,302.67
Pendimethalin	Herbicide	712	3,416.37
Prodiamine	Herbicide	305	1,663.44
Simazine	Herbicide	60	1,746.49
	Total herbicide		**37,869.29**
Acephate	Insecticide	2,191	4,844.68
Carbaryl	Insecticide	171	1,209.16
Chlorpyrifos	Insecticide	916	1,483.66
Diazinon	Insecticide	870	1,569.90
Malathion	Insecticide	1,362	4,273.11
Petroleum distillates, refined	Insecticide	431	7,535.81
Petroleum oil, unclassified	Insecticide	795	19,354.38
Potash soap	Insecticide	388	7,807.98
Methiocarb	Insecticide/ Molluscicide	162	1,034.15
	Total insecticide		**49,112.81**
Metaldehyde	Molluscicide	875	7,244.47
	Total molluscicide		**7,244.47**
	Grand total		**132,794.42**

[1]Does not include surfactants, adjuvants, or alcohol products

In 1999, all nurseries in Orange County were placed under quarantine for red imported fire ant (RIFA). As a result, all nursery material with soil leaving the quarantined area must be treated with insecticides identified by the California Department of Pesticide Regulation and California Department of Food and Agriculture to control RIFA. These include products containing chlorpyrifos (organophosphate), diazinon (organophosphate), bifenthrin (pyrethroid), and fenoxycarb (insect growth regulator). The mandated use of these materials resulted in an increase in the first three materials in Orange County from 677, 683, and 46 pounds of active ingredient, respectively, in 1997 to **49900, 1109, and 660** pounds, respectively, in 1999 (CDPR 1999 Pesticide Use Reports[1]) (Figure 1).

Figure 1. Pounds of active ingredient of chlorpyrifos, diazinon, and bifenthrin used in Orange County, California in 1997 and 1999.



Important Pests in Container Nursery Production

We surveyed nurseries in Orange, Los Angeles, Fresno, Visalia, and San Diego regarding what their major pests were and how they controlled them. From the surveys, we extracted the top 5 pests for each category and report on them below.

Summary of Survey results:
1. Counties included in survey
San Diego
Orange
Los Angeles
San Benito
Santa Cruz
Fresno
Tulare

2. Size of production (acres) **<100** 20%
>100 80%

3. Costs of

	Average cost per month for 100 acres
Scouting	**$ 1,100**
Pesticide application	**$ 7,000**
Pesticide materials	**$ 7,500**

[1] Numbers are not exact since data was available only to November 1999. Also, PUR data is preliminary and not verified by CDPR.

4. Pest Control

Insects: Growers were asked to rank pests in order of the amount of pesticide used to control them. For growers inside the quarantine zone, the red imported fire ant was ranked as number one for all growers. Other pests that consistently ranked in the top ten for pesticide use were aphids, mites, whiteflies, mealybugs, scales, thrips, and lepidoptera. Details about these pests and their control are described in the section on Insect and Mite Control.

Weeds: Growers were asked to rank weeds in order of the amount of pesticide used to control them. Weeds that were consistently ranked in the top ten for pesticide use were common groundsel, bittercress, oxalis, prostrate spurge, liverwort, and moss. Details on these weeds are described in the section on Weed Control.

Disease: Growers were asked to rank diseases in order of the amount of pesticide used to control them. Diseases that were consistently ranked in the top ten for pesticide use were damping off (pythium, rhizoctonia), phytophthora root rot, powdery mildew, downy mildew, bacterial leaf spot, and fungal leaf spot. Details on these diseases are described in the section on Disease Control.

5. Other Important issues.

exotic pests	Red imported fire ant Whiteflies Effects of pesticides on non-target pests
pesticide runoff	Runoff during storms Chlorpyrifos, diazinon runoff Confusion over criteria for toxicity levels and limits Maintaining clean well water
ag-urban issues	Neighbor complaints Vandalism Notification of neighbors Urban encroachment (schools, houses) Effects of pesticides on the environment Nitrate runoff
other	Availability of registered materials FQPA = loss of registered materials Public conception of pesticide danger Amount of pesticide used Restriction or removal of pesticides from horticulture

6. Other pests:

Birds
Squirrels
Gophers
Raccoons
Rabbits
Rats/Mice

7. Average Rating of factors from highest to lowest (5=most important, 0=not important)

Pesticide cost	4.8
Pesticide and fertilizer runoff	4.7
Environmental regulations	4.3
Training or education regarding pests, pesticides, integrated pest management	4.3
Pesticide availability	4.0
Scheduling of pesticide application	4.0
Availability of low risk pesticides	4.0
Water recycling	3.7
Labor cost	3.0
Labor availability	2.8

Pest Descriptions, Damage and Control Options

D. INSECT AND MITE CONTROL Growers were asked to rank pests in order of the amount of pesticide used to control them. For growers inside the quarantine zone for the red imported fire ant, this pest was ranked as number one for all growers. Other pests that consistently ranked in the top ten for pesticide use were aphids, mites, whiteflies, mealybugs, scales, thrips, and lepidoptera. Details about these pests and their control are described below.

ANTS

<u>Native and Imported Fire Ants</u> ***Solenopsis invicta, S. xyloni, S. aurea, others***

Description of Pests: All fire ants belong to the genus *Solenopsis* and are characterized by having a 2-segmented petiole (the narrow waist between the thorax and abdomen), 10-segmented antennae with a 2-segment club, and a stinger. There are two native fire ant species likely to be encountered in California and confused with the red imported fire ant or **RIFA**. The more common one, the southern fire ant (*Solenopsis xyloni*), 2.5-4.5 mm in length, is found in coastal and inland regions. It is very similar in appearance to the RIFA. Besides technical differences in the shape of the clypeus requiring the use of a hand lens or microscope, the southern fire ant differs from the RIFA in that it is bicolored, with a reddish head and thorax and a dark brown abdomen. By contrast, the RIFA is an almost uniform dark reddish-brown and 3-6 mm long. Furthermore, the southern fire ant mounds are irregular craters, whereas the RIFA mounds are frequently built up into domes. *S. aurea* is almost entirely yellowish and is largely limited to the Colorado Desert in California. All three species are polymorphic, i.e., the workers are of mixed sizes. Another characteristic difference between these species is the aggressiveness of the workers. Although they will all sting, the ferocity of the RIFA is notable. Any object touching their mound is immediately attacked and stung and the workers will quickly run up a stick that touches the mound.

Damage: RIFA pose an immediate threat to the area's economy because they require a quarantine of nursery products. In quarantined areas plants cannot be shipped without labor-intensive and expensive drenching of all plants with pesticides. Furthermore, the ants indirectly impact many plants and crops because they tend and protect plant pests such as aphids and scale insects. They also chew on soft plant tissue and growing buds. Their stinging behavior can be hazardous to field workers. Newborn livestock and poultry are vulnerable to attack. They can clog irrigation lines and short-circuit electrical systems. In natural ecosystems they interfere with and displace native wildlife. Their sting is noxious and produces a pustule on the skin that can scar if it gets infected. Due to their pervasiveness in infested areas, they can degrade the quality of life. Hunters, hikers, and campers have to modify their outdoor activities so as to avoid stepping on ant mounds.

Biology: The Red Imported Fire Ant, originally introduced in the southeast, was described as having one queen per mound, or 'monogyne'. Colonies of this type are highly territorial and will fight with neighboring colonies. However, the predominant form in Texas has become the 'polygyne' form, meaning that there are many queens per colony. The polygyne fire ant can have hundreds of mounds per acre compared with the 30-40 typical for the monogyne form. Many of these mounds are connected underground so that brood and queens can quickly move between them. Polygyne ants are not territorial and can frequently mix with little fighting. Researchers have shown that the total egg production for the multiple queens exceeds that of the single queen in a monogyne colony. Thus, there are more mounds and more ants per acre in polygynous ants. Polygyne ant colonies can reproduce by budding, where some of its queens and workers advance to a new location. This process allows them to saturate a field in a relatively short time.

It is still uncertain whether the RIFA in the nurseries are monogyne or polygyne. This could have a significant impact on the effectiveness of baiting treatments.

Biological Control: The USDA and the University of Texas have begun the first biocontrol program to control fire ants. There is a tiny South American fly, called a phorid, that is a natural parasite of fire ants. It lays its egg in the neck region of the worker ant. The larva that hatches from this egg eventually consumes the ant's brains and causes the ant's head to drop off. The new fly then emerges from the head of the ant. These flies are being mass reared and released in Florida and Texas. Researchers are also investigating other parasitic insects and even protozoa from South America.

Monitoring: Presently, monitoring stations baited with Spam meat are being used at 50-ft intervals to monitor for the presence of RIFA in nurseries.

Chemical Control for Fire Ants in Quarantine Areas: In quarantine fire ant situations the USDA has approved a number of products with differing certification periods. Chlorpyrifos drenches of plants provide 30 days of certification. The longest certification is given to incorporation of Talstar® granules (pyrethroid , bifenthrin) into potting soil. The USDA certifies these treatments for 180 days. The California Department of Food and Agriculture recommends soil incorporation of the Talstar, plus treatment of the infested grounds with ant baits. Some ant baits, such as Distance and Award, contain IGRs (insect growth regulators) that reduce fire ant numbers in about 6 weeks. Others, such as Amdro (hydramethylnon) can show significant effects in several days, especially reducing the number of workers.

Alternatives: Alternatives for fire ant control are limited by quarantine regulations. Improvement of monitoring techniques to detect ants in infested areas more accurately may allow spot treatment of materials rather than treatment of all containers. Use of bait materials in stations rather than broadcasting or drenching could reduce worker exposure and risk of environmental contamination.

Argentine Ant ***Linepithema humile***

Description of Pest: The Argentine ant, *Linepithema humile* (Mayr) (=*Iridomyrmex humilis)*, is a small shiny, brown ant with a one-segmented petiole, and one size worker. Workers are about 2.2-2.6 mm in length and don't sting. *L. humile* is found throughout most of southern and central California. Argentine ants are difficult to control because they are polydomous meaning that individual colonies of ants over a large area are actually interrelated and individual ants can easily move from one nest site to another if a colony is disturbed and polygynous, colonies having many queens. Mating typically occurs in the nest and colonies spread by budding.

Damage: Argentine ants are the most important ant pest in agriculture and urban areas throughout California. *L.humile* infestations are a widespread problem for the nursery industry because infested container plants can result in delay or rejection of inter-regional shipments due to quarantines presently in place for RIFA (*Solenopsis invicta*) and other pests. Argentine ants tend colonies of homopteran pests such as aphids, scales, and whiteflies collecting honeydew as a food source and actively interfering with natural enemy activity against homopteran pests resulting in larger populations of pests when ants are present. *L. humile* is also extremely important because they will displace other ants and arthropods disrupting natural ecosystems. This is especially important in newly developing urban areas in riparian habitats.

Biological Control: Currently there are no biological methods of controlling *L. humile*. Some research is being conducted with phorid flies that appear to alter the foraging behavior of Argentine ants in Brazil, but it is unlikely that these flies could significantly reduce ant populations.

Monitoring: Argentine ants are effectively monitored with bait stations containing sugar water. Visual estimates or the amount of sugar solution consumed can be used to provide an index of foraging activity.

Alternatives: Protein baits containing hydramethylnon and fipronil (MaxForce FG) and liquid sugar baits containing boric acid are commercially available for Argentine ant control. The protein baits are generally more effective when applied in the spring and early summer. Ants typically ignore protein baits in the late summer. Consumption of the various commercially available boric acid baits is sporadic and it may take up to 8 weeks to achieve noticeable control. Studies are being conducted on the potential use of *Beauveria bassiana* (entomopthogenic fungus) for ant control.

Chemical Controls: Survey results report common materials presently used for ant control in nurseries include diazinon (65%), chlorpyrifos (50%), malathion (15%), and cyfluthrin (15%). Other materials such as acephate, bifenthrin, and baits containing pyriproxyfen, hydramethylnon, and several pyrethroids are also presently registered for use on ants in nurseries.

APHIDS **Scientific Names:** Melon aphid - *Aphis gossypii*
Green Peach aphid - *Myzus persicae*

Description of Pest: Aphids are distinguished from other insects by the presence of cornicles, tube like appendages which protrude from the rear of the aphid. There are numerous species of aphids attacking California ornamental crops. The two species which are most commonly encountered are the green peach aphid, *Myzus persicae* and the cotton or melon aphid, *Aphis gossypii.* Melon aphids are typically dark green, but color variations do occur frequently. The cornicles are relatively short, stout and always dark. Melon aphids have red eyes and antennae which only reach to the middle of the abdomen. Green peach aphid is characterized by a depression in the front of the head between the antennae and by long thin, translucent cornicles which extend beyond the tip of the body. Green peach aphids vary in color from yellowish green to rose pink. Winged adults have a dark blotch in the middle of the abdomen. Adult aphids may or may not have wings. Winged aphids arise as a result of crowding. Green peach aphids produce winged adults at lower population densities than the melon aphid. The optional temperature for GPA development is 75°F whereas optional temperatures for melon aphids are above 75°F. Adult aphids give birth to living young. Generally, aphids begin giving birth in 7-10 days, depending on temperature.

Damage: Aphids excrete copious amounts of honeydew, causing the plants to become sticky. Sooty molds then grow on the honeydew causing plant parts and areas under the plants to become blackened. Shed skins of the aphids are white, become stuck to plant surfaces, and also detract from the plant's aesthetics. Sufficient feeding can cause foliage to become yellowed, and feeding on newly developing tissues will cause those parts to become twisted as they grow. Melon aphids are known to transmit 44 plant viruses, while green peach aphids are known to transmit more than 100 plant viruses.

Biological Control: Predators such as lacewings (*Chrysoperla spp.*) and midges (*Aphidoletes aphidimyza)* are commercially available. Parasitoids, such as *Aphidius spp., Lysiphlebus testaceipes, Diaeretiella rapae, and Aphelinus abdominalis,* are also commercially available.

Cultural Control: Because this pest feeds on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for aphid populations. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens that have a pore width of 355 microns or smaller. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of aphids and other pests, and disinfested if needed.

Monitoring: Yellow sticky cards placed in greenhouses will capture winged adults. However, aphids produce winged individuals in response to crowding so scouting for infestations is an essential component of monitoring. Melon aphids also tend to have a more uniform vertical distribution on plants than green peach aphids which tends to be clustered around growing points, meaning that infestations of melon aphids under lower leaves can easilygo undetected.

Chemical Control: Survey results report common materials presently used for aphid control in nurseries include the organophosphates malathion (50% of growers), acephate (80% of growers), chlorpyrifos (15%), and diazinon (15%); synthetic pyrethroids cyfluthrin (15%), fluvalinate (15%), bifenthrin (15%), rotenone/pyrethrin (15%); the carbamate methiocarb (15%); a neem extract azadiractin (15%), paraffinic oils (30%), and potash soaps (15%). See appendix for a detailed listings of these and additional registered materials.

WHITEFLIES

Greenhouse Whitefly **Scientific Name**: *Trialeurodes vaporariorum*

Description of the Pest: The greenhouse whitefly adult is 0.9 (male) to 1.1 mm (female) long, with four wings, sucking mouth parts, and a powdery waxy coating over the body and wings that give the otherwise yellow body a white color. The wings are held nearly parallel to the leaf and cover the abdomen when the adult is at rest. There are six life stages: egg, four instars, and the adult. Females lay eggs in circles on the undersides of leaves of plants with smooth leaves; on plants with pubescent leaves, the eggs may be more scattered. Eggs are partially inserted into the leaf, initially they are yellowish, but close to hatching they turn a purplish brown. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the underside of the leaf and do not move. The end of the fourth instar is called a pupa. The pupal stage is the most important for whitefly species identification. Greenhouse whitefly pupae are oval and have vertical sides, giving the pupa a cake-like appearance from the side. Along the perimeter of the upper surface there is a fringe of filaments, there are also much larger wax filaments projecting above the upper surface of the body. The greenhouse whitefly can complete one generation in 21 to 26 days at 81°F.

Silverleaf Whitefly **Scientific Name:** *Bemisia argentifolii*

Description of the Pest: The silverleaf whitefly adult is 0.8 (male) to 1.0 mm (female) long, with four wings, sucking mouthparts. In contrast to the greenhouse whitefly, the silverleaf whitefly has limited amounts of waxy coating over the body and wings that give the otherwise yellow body a whitish hue. The wings are held at the sides of the body, partially exposing the back of the abdomen when the adult is at rest. There are six life stages: egg, four instars, and the adult. Eggs are not laid in a circular pattern, are partially inserted into the leaf, and they remain yellowish until they hatch. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the leaf and do not move. The end of the fourth instar is called a pupa. Silverleaf whitefly pupae are ovoid, but with a slightly pointed hind end and red eye spots easily visible from above. The pupa is convex and does not have a marginal fringe of filaments. The length of wax filaments projecting above the upper surface of the body varies on different hosts. Silverleaf whiteflies can complete development in 16 (86°F) to 31 (68°F) days.

Damage: Whitefly adults and immatures feed on sap. As they feed, they excrete honeydew, which is unsightly and supports the growth of sooty mold. Very large populations of whiteflies cause stunting of plant growth, and leaves may senesce and die. Physiological abnormalities, such as white stem on poinsettia, may also occur. Usually populations are not so high, and damage is due to honeydew, sooty mold, and nuisance populations of adults.

Biological Control: *Encarsia formosa,* a parasitic wasp, has long been recognized as an effective biological control for greenhouse whiteflies. Wasps are released at a rate of two to five parasites per plant for 8-10 weeks of the growing season. This sort of release program can be effective if long residual insecticides have not been applied in advance of the parasite release, and where the initial population is quite low (only a few whiteflies per plant). Greenhouse whitefly pupae turn black when parasitized by *Encarsia. Encarsia* emerge as adults through circular exit holes. *Delphastus pusillus,* a whitefly predator, has been used against silverleaf whiteflies. *Eretmocerus eremicus* is a commercially available whitefly parasite for silverleaf whitefly.

Cultural Control: Because this pest feeds on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for whitefly populations. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens that have a pore width of 405 microns or smaller. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of whiteflies and other pests, and disinfested if needed.

Monitoring: Yellow sticky cards placed in greenhouses will capture adult whiteflies. However, traps need to be used at a greater density, e.g. 1/1,000 sq. ft. than for other pests. When monitoring plant samples, it is imperative to look on the undersides of leaves.

Chemical Control: Survey results report common materials presently used for whitefly control in nurseries include the organophosphates malathion (30% of growers) and acephate (65% of growers); the fungal pathogen *Beauveria bassiana* (30%); imidacloprid (30%); IGRs pyriproxyfen (15%) and s-kinoprene (15%), pyrethroids cyfluthrin (15%), fluvalinate (50%), bifenthrin (15%); and paraffinic oils (15%) See appendix for a detailed listings of these and additional registered materials..

MEALYBUGS

Foliar Feeding Mealybugs **Scientific Names:** Citrus mealybug - *Planococcus citri*
Mexican mealybug - *Phenacoccus gossypii*
Longtailed mealybug - *Pseudococcus longispinus*

Root Mealybugs **Scientific Name:** *Rhizoecus spp.*

Description of the Pest: These slow moving sucking insects have a loose waxy coating on the body that gives them their mealy appearance. The citrus mealybug is heavily and evenly covered with white, powdery wax, except for a fainter narrow shreak down the middle. It has short, wax filaments, along the sides and hind filaments about ¼ the length of the body. Both the citrus mealybug and the Mexican mealybug lay eggs in ovisacs (within masses of cottony wax). The Mexican mealybug can be distinguished from the citrus mealybug by four rows of thinly waxed depressions down the back. The longtailed mealybug has four long terminal wax filaments held parallel to the axis of the body, and gives live birth to young. Mealybug infestations often occur underneath foliage, and in difficult to reach cracks and crevices. Root mealybugs are below-ground dwelling mealybugs, feeding on the roots of plants. These mealybugs have a thin, uniform waxy coating and lack the terminal wax filaments typical of their foliar-feeding relatives.

Damage: Mealybugs remove sap from the plants, causing yellowing of leaves and decline. Mealybug ovicacs and the honeydew excreted by mealybugs are unsightly. Honeydew allows the growth of sooty mold fungi and attracts ants, which then carry mealybugs to uninfested plants. The only outward sign of root mealybug feeding may be a decline in the health of infested plants. When plants are removed from the pot, the whitish mealybugs feeding on the roots are then observed.

Biological Control: *Cryptolaemus montrouzieri*, the mealybug destroyer ladybeetle, is an effective predator of citrus and Mexican mealybugs and other ovisac-forming sucking insects, such as green shield scale. Larval mealybug destroyers look like large, faster-moving mealybugs, but are readily distinguished by their chewing mouthparts. *Leptomastix dactylopii*, a parasite of citrus mealybugs, is also commercially available. Effective predators or parasites of longtailed mealybugs are not yet commercially available. Biological control for root mealybugs has not been investigated.

Cultural Control: Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of mealybugs and other pests, and disinfested if needed.

Monitoring: Look for signs of honeydew, including ant activity. Regular inspect plants. Include root-ball examinations when scouting, and when plants showing decline are observed.

Chemical Control: Survey results report common materials presently used for mealybug control in nurseries include the organophosphates malathion (30% of growers), acephate (50% of growers), and chlorpyrifos (30%); the chloronicotinyl imidacloprid (15%); the pyrethroid fluvalinate (15%); and paraffinic oils (50%). See appendix for a detailed listings of these and additional registered materials.

SCALES

Soft Scales

Scientific Names: Brown soft scale - *Coccus hesperidium*
Hemispherical scale - *Saissetia coffeae*
Black scale - *Saissetia oleae*
Green shield scale - *Pulvinaria psidii*

Description of the Pest: Soft scales are typically found on woody plants and foliage plants. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the leaf or twig and (with the exception of green shield scale) do not move. These scales typically have a more conspicuous profile from a side view compared with armored scales, and produce copious honeydew. The protective covering of soft scale cannot be separated from its body. Hemispherical scale adults are strongly convex, hard, brown, smooth and shiny. Black scale adults are globular and hardened with ridges in the back that look like the letter "H". Green shield scale, introduced into California approximately in 1992, has a light yellow green color as an immature, then parthenogenetically (without mating, there are no males) produces a mass of eggs in a cottony ovisac.

Damage: Soft scales remove sap from the plants, causing yellowing of leaves and decline. Green shield scale ovisacs and the honeydew excreted by all the soft scales are unsightly. Honeydew allows the growth of sooty mold fungi and attracts ants, which then carry scales to uninfested plants.

Biological Control: The black scale parasite, *Metaphycus helvolus,* has also been used for control of the closely related hemispherical scale. The mealybug destroyer, *Cryptolaemus montrouzieri,* is known to be an effective predator of green shield scale. Green shield scale, however, is a CDFA "A" rated quarantine pest, so plant material must be entirely free of its presence to be shipped.

Cultural Control: Exclusion of wind-blown crawlers can be accomplished by covering openings to the greenhouse with fine-mesh screens. Prune out and discard heavily infested plant parts. New plants should be carefully inspected to ensure that they are free of scales and other pests, and disinfested if needed.

Monitoring: Double-sided sticky tape wrapped around infested stems are useful for determining when crawlers are active.

When to treat: Optimum treatment timing is when crawlers are active; however, this can be difficult when there are overlapping, multiple generations.

Armored Scales

Scientific Names: Oystershell scale - *Lepidosaphes ulmi*
Greedy scale - *Hemiberlesia rapax*
California red scale - *Aonidiella aurantii*
Oleander scale - *Aspidiotus nerii*
San Jose scale - *Quadraspidiotus perniciosus*

Description of the Pest: The protective covering over armored scales is produced by molted skins and secretions from the scale. Unlike soft scales, armored scale bodies can be separated from their protective coverings. High populations of these sucking insects give plant stems a crusty appearance. The first instar is called a crawler and has functional legs, while the remaining instars are attached to the leaf and do not move. Unlike soft scales, however, the armored scales do not produce honeydew.

Damage: Along with the unaesthetic encrustations, these scales inject toxic saliva that will cause the plants to decline.

Biological Control: *Aphytis melinus* is a commercially available parasite effective on California red scale.

Cultural Control: Prune out and discard heavily infested plant parts. Exclusion of wind-blown crawlers can be accomplished by covering openings to the greenhouse with fine-mesh screens. New plants should be carefully inspected to ensure that they are free of scales and other pests, and disinfested if needed.

Monitoring: Double-sided sticky tape wrapped around infested stems are useful for determining when crawlers are active. Optimum treatment timing is when crawlers are active; however, this might be difficult when there are overlapping, multiple generations.

Chemical Control: Survey results report common materials presently used for scale control in nurseries include the organophosphates malathion (15% of growers), diazinon (30%), acephate (30%), and chlorpyrifos (30%); the pyrethroid fluvalinate (15%); potash soaps (15%) and paraffinic oils (65%). See appendix for a detailed listings of these and additional registered materials.

THRIPS **Scientific Name:** Western Flower Thrips - *Frankliniella occidentalis*
Greenhouse Thrips - *Heliothrips haemorrhoidalis*

Description of the Pest: Thrips adults have four feather-like wings, each consisting of a thick supporting strut with fine hairs on the front and hind edges. Thrips go through six life stages: egg, first instar, second instar, prepupa, pupa, and adult. These thrips insert eggs into the plant tissue. The first two instars and the adults feed by piercing and removing the contents of individual plant cells. Western flower thrips usually feed in enclosed tissues such as flowers, buds, or growing tips. Adults also feed on pollen and on mites. The prepupal and pupal stages take place in the soil beneath the infested plant. Females will lay male eggs if unmated, both sexes if mated. Development times to complete on generation of western flower thrips varies from 11 days (77° - 87°F), to 44 days (27°F).

Damage: Direct feeding damage includes streaking, spotting, and tissue distortion. Western flower thrips can vector tomato spotted wilt virus. Flower thrips activity can cause premature senescence of flowers because of their pollination activity. On orchids, flower thrips feeding will leave translucent 'pimpling' spots on petals. Greenhouse thrips stipple the foliage of numerous field and greenhouse grown plants. The stippling damage caused by thrips feeding on individual cells is often confused with mite stippling. Thrips feeding is often accompanied, however, by black, varnish-like flecks of frass.

Biological Control: Three commercially available predators are the minute pirate bug, *Orius tristicolor*, and two predatory mites, *Neoseiulus cucumeris* and *Hypoaspis* mites. Minute pirate bugs are polyphagous, and will also feed on aphids, mites, and small caterpillars. *Orius* are released at a rate of 2000 to 4000 per acre, while *Neoseiulus cucumeris* are released at a rate of 10 to 50 mites per plant for each of 2-3 weeks. These mites will also feed on spider mite eggs, pollen, and fungi. *Hypoaspis miles* are soil inhabiting predators, which feed on thrips prepupae and pupae in the soil. These mites are generally released in the soil at planting.

Cultural Control: Because this pest feeds on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for thrips populations. Most commercially available screens have pore sizes slightly larger than the width of the western flower thrips thorax (145 microns), meaning that some winged adults can penetrate these openings. However, covering openings to the greenhouse with fine screens does exclude most thrips. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of thrips and other pests, and disinfested if needed.

Monitoring: Blue sticky cards are most attractive to western flower thrips. However, yellow cards are good predictors of WFT populations, are easier to count and are more commonly used for general-purpose insect monitoring.

Chemical Control: Most insecticides must be applied at least 2 times, 5-7 days apart, for efficacy against western flower thrips. Survey results report common materials presently used for thrips control in nurseries include the organophosphates acephate (50% of growers), and chlorpyrifos (30%); the pyrethroid fluvalinate (15%); the spinosyn spinosad (100%); and the carbamate methiocarb (15%). See appendix for a detailed listings of these and additional registered materials.

LEPIDOPTERA

Armyworms and Cutworms **Scientific names:** Beet armyworm: *Spodoptera exigua*
Yellowstriped armyworm: *Spodoptera ornithigalli*
Variegated cutworm: *Peridroma saucia*

Descriptions of the Pests: Beet armyworm is the most frequently encountered of the three species listed above. Adults are heavy-bodied moths (wingspread 25 to 28 mm) with a characteristic mustard or orange colored liver-shaped spot narrowly ringed with white on the forewings. The female lays egg masses on the undersides of leaves, covering the eggs with a felt made from her body hairs. The first through the third instar larvae often feed gregariously, skeletonizing the undersides of leaves, or they feed on the insides of buds. Later instars disperse and feed individually, chewing entirely through leaves of flowers. Early instar larvae are small and green, while late instar larval color may be green, brown, black, or gray. In all instars, there are fine lines along the length of the body, with a more conspicuous lateral stripe and a black spot just dorsal to the lateral stripe behind the head. Beet armyworm continually develops during the winter in mild areas and builds up on weeds and cultivated cotton, lettuce, and tomato fields. One generation can take as little as 31 days at 75°F and 24 days at 80°F. Egg to adult generation times can be calculated using a base threshold temperature of 10.5°C and 49 day-degrees C for the egg stage, and a base temperature of 14.5°C and 236 day-degrees C for completion of larval and pupal stages. The pre-ovipositional stage in the adult is an additional one to two days.

The yellowstriped armyworm larvae have a pair of black triangles on the back of most abdominal segments. Some larvae appear nearly completely black when viewed from above. The lateral stripe is bright orange or yellow. The adult (wingspread 38 mm) has a complex and highly contrasting pattern of brown, yellow and white on the front wings.

The variegated cutworm overwinters as a naked pupa in the soil. Adults have a 39 to 54 mm wingspread, with a distinct liver-shaped outline on the front wings. Larvae have yellow or orange spots or a broken longitudinal stripe at the top of the body; which is otherwise gray. Often there is a dark triangle or "W" shaped mark on the top of the eighth body segment.

Cabbage Looper **Scientific Name:** *Trichoplusia ni*

Description of the Pest: Loopers arch their backs as they crawl. Cabbage loopers are light green and usually have a narrow, white stripe along each side and several narrow lines down the back. The dome-shaped eggs are laid singly on the undersurfaces of older leaves. Adult moths have brown, mottled forewings marked in the center with a small, silver figure 8.

Diamondback Moth **Scientific Name:** *Plutella xylostella*

Description of the Pest: When at rest, the adult male moth's wings meet over its back to show three yellow diamonds. The 1-cm long female moths lay minute eggs singly or in groups of two or three on the undersides of leaves. Each female lays an average of 75 eggs. First instars mine leaves, then are external leaf feeders for the remaining three instars. Mature larvae are approximately 1 cm long, are pale green and wriggle actively when disturbed. An openly woven silk cocoon holds the pupa in place under leaves. Development from egg to adult is 29, 16, and 12 days at temperatures of 68, 77, and 87°F, with the greatest survival at 77°F.

Damage: Armyworms and cutworms mostly are a concern due to direct damage to flowers, and to aesthetic injury to leaves that would be marketed with the flowers. Presence of late instar larvae in seedling flats can also cause tremendous plant loss. Although moderate early-season feeding by armyworms on gypsophila may actually increase tillering and yields.

Young cabbage looper larvae feed primarily on the underside of lower leaves, skeletonizing them. Larger cabbage loopers chew entirely through leaves and flowers.

Diamondback moth larvae chew small circular holes in leaves from the undersides, giving the leaves a shot-hole appearance. Very high populations can defoliate plants. Affected flowers include sweet alyssum, stock, candytuft, and wallflower.

Biological Control: A number of parasites, both tachinid flies and parasitic wasps, attack lepidoptera larvae and reduce their population growth rate. However, most of these larvae continue feeding through to the last instar, so parasitized larvae will still damage crops. Viruses also do not usually kill the larvae until later instars. *Trichogramma spp.* are egg parasites that can be effective against cabbage looper. Diamondback moth is resistant to many insecticides; *Cotesia plutellae, Diadegma insulare, and Microplitis plutellae* are commercially available for diamondback moth. Applying insecticides other than B.t. products are likely to exclude parasites.

Cultural Control: Because these pests feed on a large variety of plant species, production areas should be kept free of weeds, which can serve as a host. Exclusion of winged adults can be accomplished by covering openings to the greenhouse with screens. Screens are especially important when lights are used at night in greenhouses to control flowering. Individual seedling flats may also be covered with screens to exclude adults and larvae. Row covers can be a practical measure to exclude moths in field production as long as the mesh prevents entry of adults and the row cover is held above the plant surface to eliminate oviposition through the fabric.

Monitoring: Use pheromone traps to determine adult flight activity and mating. This information can be used to time B.t. sprays for young (susceptible) larvae. Use regular visual inspections of plants to detect larvae and their damage.

Chemical Control: Survey results report common materials presently used for lepidoptera control in nurseries include the microbial *Bacillus thuringiensis* (Bt) (30%); the organophosphates malathion (15%), acephate (15% of growers), and chlorpyrifos (30%); the pyrethroids cyfluthrin (15%), pyrethrin (15%), and fluvalinate (15%); the spinosyn spinosad (30%). See appendix for a detailed listings of these and additional registered materials.

MITES

Spider Mites **Scientific Name:** Two-spotted spider mite: *Tetranychus urticae*

Description of the Pest: Spider mites are web-forming mites that pierce plant cells and remove their contents. All spider mites have one body segment and four pairs of legs as adults. Two-spotted spider mite adults, as the name suggests, are yellowish green with two large dark spots on their sides. These mites lay round or onion-shaped eggs, which hatch into six-legged larvae. The subsequent stages, the protonymph and deutonymph stages, are eight-legged as are the adults. Since the entire life cycle can take as little as 8 (77 to 95°F) to 28 (50 to 68°F) days, spider mites have many generations per year.

Damage: Removal of cell contents by spider mites changes the color of leaves from green to olive green, then to a dull brown as feeding increases. Undersides of leaves may have many cast skins of mites, and the webbing on foliage is unaesthetic. Plants may become severely stunted when large mite populations are allowed to feed.

Biological Control: Many different species of predatory mites are available for use under different conditions. *Phytoseiulus persimilis* and *Galendromus occidentalis* have been used to control mite populations in greenhouses and field situations. These predators can reproduce faster than their prey, yet best results have been obtained when they are released into the crop well before the spider mite populations have built up.

Cultural Control: Because spider mites feed on a large variety of plants, production areas should be kept free of weeds, which can serve as refugia. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of mites and other pests and disinfested if needed.

Monitoring: Scout the crop regularly, as indirect sampling methods (such as sticky cards) are ineffective. Observe the undersides of leaves with a 10X handlens, and watch for changes in plant foliage characteristic of mite feeding.

Treatment Comments: Except as noted, the materials listed only kill active stages of mites, so more than one treatment may be necessary to break the life cycle. Follow label directions regarding reapplication times. If none are specified, try two applications a week apart.

Thread-Footed Mites **Scientific Name:** Cyclamen mite - *Phytonemus pallidus*
Broad mite - *Polyphagotarsonemus latus*
Bulb scale mite - *Stenotarsonemus laticeps*

Description of the Pest: Life stages of these mites are: egg, nymph, pseudopupa, and adult (one less stage than for spider mites). Eggs of the cyclamen mite are ½ the length of the adult, and are smooth ovals. Eggs of the closely related broad mite are distinguishable from cyclamen mite eggs, since they are studded with rows of white pegs on the egg's upper surface. Immature stages are whiter. The hind pair of legs in the adult female are thread-like, while adult males have stout legs for clasping the female. Adult males carry female pseudopupae on their back. As soon as the adult female emerges, they mate. Cyclamen mite is generally found feeding on growing terminals, in buds or unfolding leaflets. Their development is optimal under moderately warm (60° - 80°F) and high humidity (80 - 90%) conditions. Broad mite is similar to cyclamen mite, but is found more generally on the plant on the undersides of leaves. Mites disperse between plants on air currents and through mechanical transport. These mites can complete one generation in 7 to 21 days, depending on temperature. Female bulb scale mites lay up to 28 eggs. Adults are usually found between the scales of the bulb and the neck region. These mites overwinter in bulbs between the scales, emerging as the leaves grow. They re-enter bulbs as they dry in the field. One generation can be completed in approximately 7 weeks under field conditions.

Damage: Feeding by cyclamen and broad mites is easily recognized on all hosts because affected leaves become characteristically cupped, dwarfed and thickened, and the internodes are greatly shortened. Broad mite damage occurs more generally over the plant than cyclamen mite damage. Bulb scale mites feeding in developing shoots can cause longitudinal bronze streaks of discoloration, horizontal cracks, distortion, and death of leaves and flowers.

Biological Control: *Neoseiulus californicus* and other species of predatory mites have been used for broad mite and cyclamen mite control.

Cultural Control: Because these mites feed on a large variety of plant species, production areas should be kept free of weeds, which can serve as reservoirs for mite populations. Plants being brought in to start a new crop should be carefully inspected to ensure that they are free of pests, and disinfested if needed. Disinfestation can be accomplished by immersing propagation stock in 110.3°F water for 30 minutes, or treatment at 100% relative humidity and 110.3°F for 1 hour. If hot spots of these mites are found in production areas, consider roguing affected plants and treating the surrounding plants.

Monitoring: Visually inspect plants for typical damage symptoms as part of a weekly scouting program.

Chemical Control: Survey results report common materials presently used for mite control in nurseries include the carboximide hexithiazox (50%); the macrocyclic lactone abamectin(65%); the organochlorine dicofol (50%); the pyrethroids fluvalinate (30%) and bifenthrin (15%); potash soap (15%); and paraffinic oils (50%). See appendix for a detailed listings of these and additional registered materials.

Portions of the above section were extracted from Robb et al., 2000.

Other Issues for Insect Pests

The threshold for insect pests on ornamental plants is extremely low. Consumer acceptance at a retail level is one concern. Because much of the plant material grown in California is shipped to other states, restrictions on shipping material contaminated with insect pests can result in rejection of shipments with any pests found on plants.

Many growers select organophosphate materials to control insect pests in the nursery. This may be due in part to their broad range of activity against the many insect pests that are found in the nursery. In order to reduce the use of organophosphates, it will be necessary to provide a combination of new cultural, biological and chemical options that can effectively control all pests found in the nursery.

Mandatory use of certain chemicals on all containers in quarantine areas to control fire ants limits ability to reduce risk. Possible methods of reducing overall amounts of insecticides in nurseries include improved monitoring techniques to accurately detect the presence of fire ants and allow treatment of infested areas only. The use of bait stations to confine insecticides rather than broadcasting will reduce possible runoff and worker exposure. In addition, baits would reduce the need for broadcast spray and granular applications.

The wide range of plant materials and varieties grown with variable susceptibility to pest pressure may result in treatment of an entire range of crops rather than infested sections only. Scouting of crops on a regular basis can allow early detection of pests and spot treatment of problem areas before they become wide spread.

Weed Control: Nurseries reported that their top weed problems were oxalis, spurge, common groundsel, bittercress, and liverworts and mosses. The methods of control are summarized in Table 2. Most growers use a regular weed control program that they would regardless of weed spectrum. This usually consisted of a preemergent herbicide combination followed by handweeding and a non-selective herbicide. Growers vary the preemergent herbicide based on crop sensitivity rather than weeds controlled.

In general, weeds associated with container production are continual problems due to their year-round production of seeds and effective dispersal of seeds. Whenever weeds are found in containers, their value is reduced because these weeds are than be introduced in to the landscape when planted there. A heavy infestation of weeds will reduce plant growth, particularly root growth, by competing for water and nutrients.

Table 2. Summary of grower response to survey. Number indicates the percentage of growers that used a herbicide or other method to control that weed.

	CG	BC	OX	SP	LW	MO
Rout	43	43	43	43	0	0
Gallery	43	43	43	43	0	0
Ronstar	14	14	14	29	0	0
OH2	43	43	43	43	14	0
Oxyfluorfen	29	29	29	29	0	0
Roundup	29	29	43	14	0	0
Reward	29	29	14	29	29	0
Scythe	0	0	0	0	14	0
Pendamethalin	29	29	29	29	0	0
Surflan	43	43	43	43	14	0
Prodiamine	29	29	29	29	29	29
Ferrous sulfate	0	0	0	0	29	29
Handweed	86	86	86	86	86	29
Mulch[1]	29	29	29	29	29	29

CG=common groundsel, BC=bittercress, OX=oxalis, SP=spurge, LW=liverwort, MO=moss
[1]Mulch is organic (bark, pecan shells, etc.) or synthetic fabric disks.

<u>Woodsorrel</u> (*Oxalis* spp.)
(Elmore and Cudney. 1999).
Description: Creeping woodsorrel, *Oxalis corniculata*, and yellow woodsorrel (*O. stricta*) are common weeds found growing in nursery containers. There is also a purple-leafed subspecies, *O. atrapurpurea*. Woodsorrel grows in both full sun and shaded areas that receive adequate moisture. Creeping woodsorrel is a perennial plant that grows in a prostrate manner and forms roots along its stems where nodes contact the soil. Yellow woodsorrel is also perennial but grows in a slightly more upright manner and does not root at the nodes. Flowers of woodsorrel can be found almost anytime during the year but spring is the period of heavy flowering and seed formation. Seed are borne in erect, cylindrical pods. When seed pods mature, they burst open and forcefully expel the seeds, which may land 10 feet or more from the plant. Because seeds are rough, they adhere to surfaces of machinery, containers which may have dirt on the outer surfaces, or clothing. There are about 10 to 50 seeds per pod and a single plant can produce more than 5,000 seeds. Light is required for germination. Optimum seed germination occurs at temperatures between 60° to 80°F, though some germination occurs at lower temperatures. The seeds can germinate any time of year, but most plant establishment takes place in fall.

Damage: Woodsorrel is a major weed in nurseries. As seed pods mature and expel seeds, creeping woodsorrel spreads from container to container. Hand-weeding is used extensively to reduce infestations, even though it is expensive.

Biological control: None

Cultural control: The primary methods of managing woodsorrel are to remove the established plant and to try to control the germinating seeds. Seedlings can be controlled by continual hand-weeding. It is important to remove the weeds before they set seed. When older plants are pulled out, the rootstock often breaks off and remains in the soil and woodsorrel will regrow.

Chemical control: Several preemergence herbicides are available to control germinating seeds in containers, including pendimethalin, oryzalin, oxadiazon, isoxaben, dithiopyr, and combinations of oxyfluorfen and oryzalin, or isoxaben and oryzalin (Snapshot). Burying seeds or covering them with mulch to block their exposure to light prevents germination. Woodsorrel seedlings may grow at the base of plants, where they escape preemergence herbicide treatment or poke through mulches.

Growers used preemergent herbicides Rout, Gallery, OH2, and Surflan to control woodsorrel. If the weed was found in the container 43% of the growers used Roundup. Most (86%) used handweeding in combination with herbicides.

Other methods of control: It is not known how long seeds remain viable in the soil, however, germination is inhibited or stopped when seeds are exposed to moist, warm (97°F) conditions for 30 minutes.

Prostrate spurge (***Euphorbia (=Chamaesyce) humistrata***) **and spotted spurge (*Euphorbia (=Chamaesyce) maculata*),**
(Cudney and Elmore, 1999)
Description: Spotted spurge and prostrate spurge are similar to each other but prostrate spurge roots at the nodes. They are identified as some of the worst weeds in container production throughout California. These plants are low-growing annuals that often form a dense mat on the potting media surface. Although there are other plants classified as spurges, for the sake of brevity in the following sections, "spurge" will refer only to spotted and prostrate spurge.

Spurge is a summer annual that produces numerous seeds starting within 5 weeks from germination. Seeds can remain dormant in the soil until conditions are suitable for germination. Seeds that are produced in summer germinate readily whereas those produced in late fall are mostly dormant and won't germinate until spring. Optimal germination isbetween 75° and 85°F, but the range is 60°-100°F. When moisture is available, germination can occur almost any time of the year. Light is also required for maximum germination, and seeds buried greater than 1/2 inch will not germinate well.

Damage: Spurge can compete with young plants and reduce growth. It also provides habitat for ants and snails and can be an intermediate host for fungal diseases of cultivated crops. Infested areas must be constantly monitored to hand-pull new plants before they produce seed.

Biological control: None

Cultural control: Germination can be reduced by a layer of mulch. Mulches can effectively limit spotted spurge if they prevent light from reaching the seed.

Chemical control: Preemergence herbicides will control spurge if applied before emergence of the weed. These herbicides include pendimethalin, oryzalin, oxadiazon, prodiamine, and isoxaben. There are no selective herbicides that will control spurge once it is established.

Growers used preemergent herbicides Rout, Gallery, OH2, and Surflan to control spurge. If the weed was found in the container 57% of the growers used Roundup or Reward. Most (86%) used handweeding in combination with herbicides.

Common groundsel (*Senecio vulgaris*)
(Ayeni et al. 1999, Wilen et al. 1999)
Description: Common groundsel is an early spring weed in most areas, but can grow all year in coastal areas of California. Common groundsel grows well in most shaded areas such as the environment found under the canopy of container plants. Seeds can be produced very quickly and are dispersed easily by wind. Common groundsel can complete its life cycle in as little as 8 weeks. The plant habit is upright and branched. Flowers are produced in an indeterminate fashion. Because the seed is windborne, it is important to control weeds that are found around the nursery as well as those in the containers.

Damage: Common groundsel reduces the salability of plants and increases cost of production due to need for control. Infested areas must be constantly monitored to pull new plants before they produce seed.

Biological control: None

Cultural control: Germination of common groundsel seeds in the containers can be reduced if a layer of mulch is used to reduce the establishment of wind-blown seeds. Mulches can effectively limit common groundsel invasion if the mulch surface dries out quickly.

Chemical control: A non-selective herbicide can be used to control weeds surrounding the nursery. However, it is important to control the plants prior to flowering since seeds may still develop on an otherwise incapacitated plant. Preemergence herbicides will control common groundsel if applied before emergence of the weed. Effective herbicides for preemergence control include oxadiazon, oxyfluorfen, napropamide, and isoxaben as well as combinations of herbicides such Rout, XL, and Snapshot that contain these active ingredients.

Growers used preemergent herbicides Rout, Gallery, OH2, and Surflan to control common groundsel. If the weed was found in the in the container 58% of the growers used Roundup or Reward. Most (86%) used handweeding in combination with herbicides.

Bittercress (*Cardimine* spp.)
(Ayeni et al., 1999)

Description: Bittercress is a member of mustard family and can complete its life cycle in as little as 6 weeks. It is a low growing plant (2-6") that prefers growing in shaded, moist conditions, such as those found in shade houses and under the canopy of irrigated plants. Optimal conditions for growth are between 45 and 85°F, good moisture and moderate to high fertility.

The tiny seeds are produced in a thin capsule that shatters upon maturity, forcefully spreading the seeds up to 3 feet away. There are 18-28 seeds in each capsule. Seeds do not have a dormancy period and may germinate immediately. Seeds may be carried in runoff water or moved by water splashing.

Damage: Bittercress competes with the crop for water and nutrients. The presence of bittercress in the container reduces salability of crop and increases the chance that the weed will spread to othe containers and other areas of the nursery.

Biological control: None

Cultural control: Because of the short lifecycle of this weed and lack of dormancy of the seeds, it is important to monitor all areas for this weed. Not only should containers be inspected but also areas surrounding containers. Water should not be allowed to flow over this weed when draining since this will spread the seeds. Also, recycled water should be treated or screened to avoid reintroduction of this weed. Irrigation tubes should be wiped before replacing in an uncontaminated contained because seeds could be present on the tubing.

Chemical control: Postemergent herbicides can be used to control bittercress in areas surrounding the containers but there is no selective material for use in a container. Preemergence herbicides are effective but care must be taken that the herbicide is applied prior to seed germination. Where bittercress is known to be problem, the herbicide must be applied as soon as possible and reapplied as needed. Over time, this will reduce the bittercress population. Preemergence herbicides effective for controlling bittercress include isoxaben, oxadiazon, and oxyfluorfen.

Growers used preemergent herbicides Rout, Gallery, Surflan, and OH2 to control bittercress. If the weed was found in the in the container 58% of the growers used Roundup or Reward. Most (86%) used handweeding in combination with herbicides.

Liverwort (*Marchantia polymorpha*) and Moss (*Bryum argenteum*)
(Anon, 1998, Svenson, 2000)

Description: Mosses and liverworts are Bryophytes (non-vascular plants). They do not produce seeds, rather sexual reproduction is by spores. These plants grow in moist areas because they require water for fertilization and, since they do not have a vascular system, they must absorb water through pores in the vegetative portions of the plant.
Their reproductive cycle involves alternating gametophyte and sporophyte generations.
These weeds can enter the nursery as spores but also can be introduced through vegetative means via contaminated liners. Liverwort produces gemmae (small budlike structures that detach from the parent plant and are vegetative propagules) and are also spread vegetatively by the leafy-like thallus. Moss and liverwort spores can be carried by air and be spread through the nursery.

Damage: Liverwort and moss are serious problems in nurseries due to the frequent irrigation schedule and high levels of fertility. These pests reduce root growth and can harbor other pests. High pressure from these weeds can reduce plant growth dramatically.

Biological control: None

Cultural control: The impact of liverwort and mosses can be reduced through good sanitation such as disinfecting benches when potting and not reusing containers.

Because water is critical to these plants' reproduction, water management is very important in managing these weeds. Good drainage and less frequent irrigation will reduce the impact of liverwort and moss. Coarse mulches inhibit growth of these weeds because they dry quickly and are not a good substrate for these non-vascular plants.

High N levels (100-200 mg/liter (ppm)) also promote liverwort and moss growth. Therefore, lowering nitrogen rate or using a slower release form may reduce their growth. However, the micronutrients zinc, iron, or copper may control liverwort and mosses but care must be taken to not overapply and reach toxic levels.

Chemical control: Regular sanitation with greenhouse disinfectants can kill spores that land on potting areas. There are materials that will kill liverwort and mosses but are not registered in California. For example, a combination of X-77 surfactant and Captan 50W can control of moss in containers. New products that show potential for controlling moss and liverwort are Zero Tol (ZT). This is a general disinfectant that attacks liverwort, mosses, algae, bacteria, and fungi through oxidation. Mogeton is a herbicide currently used in Europe to control liverworts in container nurseries. Another material, Debco's Liverwort and Moss Control preparation (450g/l dichlorophen) is also in use outside the U.S.

Combinations of chemical and cultural control: Svenson (see reference below) conducted a series of experiments to study how irrigation practices interact with other cultural procedures to influence liverwort development. The best treatment for liverwort suppression in this study was a combination of hazelnut shell mulch, and the application of oxadiazon at label rates. This combination provided good suppression for up to 12 weeks provided irrigation was not frequent.

Most growers used handweeding as the primary method to control liverwort. Herbicides used were prodiamine (29%) and OH2 (14%) for preemergent control and Scythe, Reward, or

Roundup (57% total) for postemergent control. Ferrous sulfate, mulching, and compost was also used.

General Nursery Weed Control
(This section is adapted from Derr et al., 1997)

Because of the high value of container nursery crops and the limited number of selective herbicides available, growers often resort to hand weeding for postemergent weed control when the weed is growing in the container. Most weed control measures for container production are based on preventing the establishment of weed seeds that have blown in from surrounding areas. This usually entails applying preemergence herbicides to the potting mix surface soon after the containers are placed in the growing area. Production systems for container ornamentals will generally involve the creation of a weed-free, well-drained site for containers. Gravel, concrete, or a surface covered with a geotextile (landscape fabric) is commonly used. After plants are established, both pre- and postemergence herbicides are applied from one to five times throughout the year for weed management. Hand pulling of escaped weeds is necessary to reduce seed sources in the nursery. The source of most weeds in a container nursery may be from contaminated liners or weeds growing in, between, or near pots. Potting mix is usually weed free.

When weeds escape preemergence herbicides, postemergence herbicides can be used to control existing weeds providing that the crop is not injured. Common postemergence herbicides used in the nursery are glyphosate, diquat, and fluazifop-P-butyl. The majority of these materials are not used in the containers themselves, but rather in areas surrounding the containers or growing area. The postemergent herbicides are useful to kill weeds before they produce weed seed that can blow or move into the container. Weed management is also helpful to reduce insect pressure since many weeds are alternate hosts for insect pests such as aphid, whiteflies, and thrips. Herbicides registered for use in nurseries are listed in the appendix.

Caution must be taken when applying herbicides in container nurseries due to runoff. Ways to reduce runoff include the following:

1. Use herbicides with low water solubility
2. Spot treat
3. Use low volume applications
4. Use only as much water as needed to move the herbicide into soil when doing water activation (e.g. with dinitroanilines). This is especially important at the time of the first irrigation.

Container spacing can also affect herbicide loss when granular herbicides are applied. Can tight spacing can reduce herbicide loss by 50% over cans spaced 8" apart. Additionally, herbicide loss can be reduced if drop spreaders are used rather than rotary spreaders.

Alternative methods of herbicide application being tested include the use of tablets containing herbicide for slow release of the product and herbicide impregnated cloth.

The following is a list of herbicides labeled for use in various ornamentals with some comments regarding their use.

<u>Preemergence herbicides that control grasses better than broadleaves:</u>

Surflan (oryzalin): Can cause girdling of certain ornamentals at the soil line. Young hemlocks are particularly susceptible to root inhibition and girdling from Surflan. Seedlings of douglas fir and true firs (*Abies* species) up to about three years of age are also affected, but pines, taxus, arborvitae and junipers are more tolerant. Stems of Monterey pines may exhibit some swelling. Often used in combination with other herbicides to widen weed spectrum controlled. Most broadleaf woody plants are quite tolerant.

Treflan (trifluralin): In the same class of herbicides as Surflan (dinitroanilines), but it is not as stable on the soil surface and must be incorporated with irrigation, or covered with a mulch, very soon after application. Often mixed with other herbicides to widen weed spectrum controlled.

Factor (Prodiamine): Another dinitroaniline that is stable on the soil surface. It will not provide as long weed control as Surflan at the maximum label rates for both.

Pendulum (also sold as Southern Weedgrass Control) (pendimethalin): In most cases, pendimethalin will probably not control a broad enough spectrum of weeds to rely on it as a "stand alone" product, should be in some combination with an additional material. Controls oxalis and spotted spurge.

Devrinol (napropamide): Safe on many woody plants but has some weaknesses in controlling broadleaf weeds, such as members of the nightshade and aster families, spurge, chickweed, and oxalis. It is an excellent grass herbicide. Generally less efficacious but often safer than the combination herbicides, useful in the herbaceous market.

Dacthal (DCPA): Generally less efficacious but often safer than the combination herbicides and still have a place in the container industry-particularly in the herbaceous market.

Pennant (metolachlor): Useful on field and container-grown ornamentals - provides preemergence control of yellow nutsedge, galinsoga, and annual grasses. Pennant provides season-long control of annual grasses. With pines and certain deciduous plants, over-the-top sprays of Pennant should be on dormant stock, before budbreak. Pennant EC distorts the newly-forming needles of pines and causes contact injury on certain actively-growing deciduous plants.

<u>Preemergence herbicides that control broadleaves better than grasses:</u>

Princep (simazine): Princep is especially effective on fleabane, horseweed, and many other broadleaf annuals. It controls a broad spectrum of weed species, provides season-long control, is safe on a wide range of nursery crops, and is very inexpensive. Princep is injurious to several nursery crop species including Euonymus, lilac, maples, Forsythia, Hydrangea, and Philladelphus, as well as most herbaceous ornamentals. Occurrences of triazine resistant weeds in nurseries have increased in recent years. Problems with groundwater contamination reported.

Ronstar (oxadiazon): Used during the growing season. Granular Ronstar has broad safety in woody plants. Has a relatively long residual, 12 to 16 weeks. Safest to the crops when applied as granules. Ronstar is weak on certain broadleaves including spurge, galinsoga, pearlwort, chickweed, and horseweed.

Goal (oxyfluorfen): Goal cannot be safely sprayed over most deciduous plants. Granular oxyfluorfen (in OH2, Rout) can cause injury if left on the foliage of container plants of if applied on tender moist foliage to begin with. If foliage is tender, oxyfluorfen must be washed off immediately after application. Goal is registered for over the top applications in many conifers but will severely injure most broadleaf ornamentals. Directed applications which avoid contact with foliage and "green" stems may be utilized around many woody ornamentals. May have a relatively short residual if under frequent irrigation. Safest to the crops when applied as granules. Goal does not effectively control horseweed or common chickweed.

Gallery (isoxaben): Excellent material for broadleaf weed control. May be an alternative to simazine (Princep). Gallery's major weakness is its inability to control annual grasses, therefore often mixed with Surflan or other grass herbicides. Some broadleaf weed species can be controlled for up to 18 months with the labeled usage rates. Gallery is safe on a wide range of woody ornamentals. Gallery does not effectively control primrose, mallow, sida, and related species. Susceptible nursery crops are lilac, *Euonymus alatus compacta*, legumes, and members of the figwort family. Some herbaceous ornamentals such as Veronica and Digitalis, which belong to the latter family, may be killed by postplant, preemergence applications of Gallery.

Casoron (also Dyclomec and Norosac) (diclobenil): A dormant season application of Casoron can control many seed-propagated perennial broadleaf weeds and provide residual control through early summer. It provides postemergent control of winter annual and perennial weeds, eliminating the need for cultivation and hand weeding in the spring. Roses are a tolerant species. The drawbacks include high cost and a limited number of ornamental species over which it may safely be used. Good for equisetum (horsetail) and mugwort control.

<u>Preemergence combinations:</u>

Rout (oryzalin + oxyfluorfen)
OH2 (Ornamental Herbicide II) (oxyfluorfen + pendimethalin)
XL (benefin + oryzalin)
Regal O-O (oxadiazon + oxyfluorfen)
Regalstar II (prodiamine + oxadiazon)
Snapshot (trifluralin+isoxaben)

<u>Postemergence Herbicides:</u>

Non-selective:

Roundup Pro (glyphosate): This herbicide can be used alone or combined with a preemergence herbicide to kill established weeds using shielded knapsack applicators. Do not use in "over the top" applications.

Scythe (pelagonic acid): Control of young annual weeds, contact activity only, affects only green tissue. Must be applied at high rates in high volumes of water.

Reward (diquat): Control of young annual weeds, contact activity only, affects only green tissue. Works well under cool temperatures.

<u>Selective postemergence broadleaf herbicides:</u>

Goal (oxyfluorfen): Postemergence applications of Goal will control certain annual broadleaf weeds. It is effective only on certain young, seedling weeds, especially malva; perennial broadleaf weeds will be burned but not controlled. Activity is enhanced if a surfactant or crop oil is added. Directed applications which avoid contact with foliage and "green" stems may be utilized around many woody ornamentals. Spruces and true firs are injured by Goal during their early flush but after about five weeks of new growth, they become tolerant.

Postemergence grass herbicides:

Fusilade (also Ornamec, Takeaway) (fluazifop-p-butyl): Kills only grasses, however it will not control annual bluegrass or hard fescues. It is most effective on young actively growing grasses. Fusilade has injured certain azalea cultivars, especially at high rates of application, causing spotting and necrosis on the leaves. Certain junipers also are sensitive to fluazifop products.

Alternatives to herbicides:

Mulches

Bark, pecan shells, straw, and other organic material can be used to help suppress weeds in containers. Weed control is likely due to the mulch staying drier than the potting mix surface, therefore, not being a good site for weed seed germination and establishment. Synthetic materials (geotextiles) can also be used as mulches. These fabric disks are circles cut to the size of the container with a slit to fit around the plant. They are available with copper hydroxide on one side to prevent weed seed germination. Advantages are they can last up to three years, disadvantages include the labor required to apply to each container and weeds may grow in areas not covered well, such as along the slit or edges of pot (Wilen et al. 1999)

Subirrigation

Subirrigation is effective for controlling weeds where there is little rainfall. Pots are placed in trays or troughs and water is drawn up through the potting mix via capillary action. Only enough water is supplied to be drawn up to the lower 2/3 of the container. In this manner, the top of the potting mix remains dry and not a good substrate for weed seed germination. This is similar to the ebb and flow system used in some greenhouses. There are limitations to this method of irrigation. First, care must be taken that plants do not sit in water for an extended period. Secondly, techniques must be created that will allow growers to use this methodology on a large scale (Wilen et al. 1999). Sand beds have been used in Oregon to adapt this technique to a larger scale but problems still exist, such as algae growing on the sand.

Disease/nematode Control: Nurseries reported that their top disease problems were damping off, phytopthora, powdery mildew, downy mildew, fungal leaf spot, and bacterial leaf spot. The methods of control of the growers surveyed are summarized in Table 3. Nematodes were not reported to be a problem, probably because plants are grown in soilless mixes. There is no tolerance for diseases because they dramatically reduce the quality of the plant. Additionally, infected plants do not thrive when transplanted into the landscape and often become more susceptible to secondary problems such as insect attack. Diseases associated with container production must be controlled throughout the crop's growth period. If they are not controlled by the time the plant is sold or if there is the chance the infect plant or plants will infect others, than the plants must be destroyed. If this occurs late in the cropping cycle, all of the investment in growing the crop is unrecoverable. Common fungicides and bactericides registered for use in nuseries are listed in the appendix.

Table 3. Diseases ranked most important to growers and the materials they use to control them. Number indicates the percent of respondents that used this chemical to control the pest.

Common Name	Class	Trade Names	DO	PT	PM	DM	FLS	BLS
		Microthiol			14			
		Safer			14			
azoxystrobin	Strobilurin	Heritage			29		14	
chlorothalonil	Substituted benzene	Daconil					57	14
Copper						14		14
copper hydroxide		Champ, Kocide					57	86
copper sulfate pentahyrate		Phyton 27			29			29
fenarimol		Rubigan			71		14	
fosetyl-al	Phosphonate	Alliette	29	86		14	14	14
Iprodione	Dicarboximide	Chipco 26019	57				14	
mancozeb	Dithiocarbamate	Protect, Dithane			29	14	43	14
mefenoxam	Phenylamide	Subdue	57	100		14		
Methyl Bromide			14	14				
myclobutanil		Systhane			43		14	
PCNB, quintozene	Chlorinated hydocarbon	Terraclor	29					
propiconozole		Banner Maxx			14		29	
Streptomycin		Agri-mycin						29
Sulfur		Microthiol			29			
thiophanate-methyl	Benzimidazole	Cleary's 3336 Domain, FungoFlo Systec 1998	100		29		71	
thiophanate-methyl mancozeb	Benzimidazole and Dithiocarbamate	Zyban			14		14	
triadimefon	Triazole	Strike			43	14	29	14
Trichoderma	Biologicals	Rootshield	29	14				
triflumizole	Imidazole	Terraguard	14					

DO = Damping Off (Pythium/Rhyzoctonia) FLS = Fungal Leaf Spot
BLS = Bacterial Leaf Spot PM = Powdery Mildew
PT = Phytopthora DM = Downey Mildew

Plant Diseases
(Extracted from: Grebus et al. 1998)

Damping-off
Pathogens: *Rhizoctonia solani, Pythium* spp., and others

Description: Damping-off is the name given to seedling diseases most often caused by fungi. As the name implies, the disease is associated with damp conditions. *Pythium* is favored by cool, wet conditions while *Rhizoctonia* can cause disease under somewhat drier and warmer conditions. Seedlings rot at soil line and are killed.

Damage: Damping off is a fungal disease that affects roots or shoots of young plants. Most plants do not recover from this disease and must be destroyed. Young plants wither and die and older plants may get brown lesions on the stems near the soil line.

Biological control: *Streptomyces griseoviridis* and *Trichoderman harzianum* are biological controls which have shown some activity in controlling root and stem rots and wilt diseases of ornamental crops caused *Pythium* and *Rhizoctonia.*

Cultural control: Damping-off can be minimized by providing good drainage because these fungal pathogens are favored by moist conditions.

Chemical control: Because there is little chance a plant can be cured of this disease, growers use soil drenches of fungicide at planting or mix fungicide into the potting mix prior to planting. Mefenoxam, fosetyl-Al (*Pythium* only), iprodione (*Rhizoctonia* and *Fusarium*), PCNB, thiophanate-methyl and triflumizole are commonly used for control. Care must be take when using these materials that resistance does not develop.

One hundred percent of the growers used thiophanate-methyl to control damping off. Fifty-seven percent of the growers also used iprodione and/or mefenozam. Trichoderma (a biological) was used by 29% of the nurseries. Other materials used were fosetyl-Al (29%), methyl bromide (14%), PCNB (29%) and triflumizole (14%). Other control measures were scouting, culling, and increasing drainage.

Powdery Mildew

Pathogen: *Erysiphe* spp., *Sphaerotheca* spp.

Description: The name of this fungal disease is from the white, powdery appearance on the surfaces of leaves and sometimes other plant parts. Powdery mildew is caused by a number of different fungi and many are host specific. Powdery mildew fungi are obligate parasites, able to survive only on living tissue. However, if cleistothecia (resting stages of the fungus) are formed the fungus can survive. On many species of perennial plants, the fungus survives as mycelium in dormant buds. Most powdery mildew fungi grow over the surface of the leaf, sending haustoria into the leaf epidermal cells. The fungi produce masses of spores, which become airborne and spread to other plants. The surface must be relatively dry for the haustoria to infect the leaf although spores may be dispersed but high humidity is also necessary for infection. Splashing water can spread the spores. Powdery mildews are favored by moderate temperatures (68°-86°F) and low light.

Damage: Leaves may yellow, then brown and die. Leaves that do not die may curl and be distorted. Leaves are covered with a grayish powder. Other infected tissues such as buds and stems may be distorted and misshapen.

Biological control: None

Cultural control: Syringing plants with water or water + surfactant in the afternoon may help keep leaves wet and reduce infections.

Chemical control: Chemical controls for powdery mildew can be preventative or curative. Care must be taken to avoid resistance to some of these fungicides.
Protectants (applied to healthy tissues before infection takes place): wettable sulfur, myclobutanil, fenarimol, triadimefon, thiophenate-methyl, propiconazole, stylet oil, triforine, neem oil.
Curatives (can be applied after disease is noted): piperalin, lime sulfur, potassium bicarbonate.

Seventy-one percent of nurseries used fenarimol to protect against powdery mildew. Other materials used were myclobutinol (43%), triadimefon (43%), sulfur spray (43%), azoxystrobin (29%), copper spray (29%), mancozeb (29%), thiophanate-methyl (14%), propiconozole (14%), and Safer soap (14%). Other control measures were pruning and washing the foliage.

<u>Bacterial leaf spots</u>
Pathogens: *Pseudomonas* spp., *Xanthomonas* spp.

Description: The bacterium survives in or on infected plant tissue. When the weather is warm and moist, bacteria ooze out of the leaf spots and are splashed to other plants. The bacteria usually enter natural openings or wounds. Spread is more severe in wet weather.

Damage: Angular, black areas on leaves. Young leaves and shoots are distorted. In severe attacks, elongated lesions form on the twigs. Bacteria ooze from infected tissues in wet weather. In severe cases, the bacterium will spread to twigs and cause girdling cankers.

Biological control: Moderate control may be achieved with preventive applications of streptomycin sulfate

Cultural control: Keep water off the leaves- use drip or microsprinklers. Remove and destroy infected tissues. Disinfect pruning tools regularly.

Chemical control: Apply cupric hydroxide or fosetyl-Al in the spring and summer to protect the new foliage. If symptoms were severe the previous year, spray with bordeaux mixture or a copper fungicide at bud break. There are no curative controls since the bacteria are systemic in infected plants.

Growers used a variety of copper compounds, especially copper hydroxide (86%) for control of bacterial spot. Some also reported that they prune out infected sections and increase spacing between plants.

Fungal leaf spots

(Adapted from Dreistadt et al. 1994)

Pathogens: many including *Pseudomonas sp., Kabatiella sp., Gloeosporium sp, Diplocarpon mespili (= Entomosporium mespili), Seimatosporium arbuti, Mycosphaerella arbuticola, Phyllosticta fimbriata, Sphaceloma sp. Alternaria, Septoria and Cercospora*

Description: Fungal leaf spots and blights usually occur when by leave are wet for an extended time and under high humidity. Fungal leaf spots are usually tan to black and concentrated along the leaf margin and veins. Often the spots will grow together and sometimes forming concentric rings of dead, brown tissue. Sporulation is often visible within dead tissue and helps distinguish it from bacterial leaf spots. Leaf-spotting pathogens survive on fallen leaf litter and on dead branches or cankers.

Damage: Discolored leaves and leaf spotting. Often infected leaves drop prematurely and in severe cases the entire tree may be defoliated.

Biological control: None

Cultural control: Avoid wetting the foliage when watering. Rake and dispose of leaves. Prune off branches showing dieback and severe leaf blight.

Chemical control: Protective sprays of thiophanate-methyl or a copper fungicide.

Growers used a number of different materials for control of fungal leaf spots. Seventy-one percent reported that they used thiophanate-methyl as well as copper hydroxide (57%) and mancozeb (43%). As with bacterial leaf spot, growers also prune and increase spacing between plants.

General information for FOLIAR FUNGICIDES
(Reprinted from: Grebus et al. 1998)

Chlorothalonil (Daconil) is effective for the control of *Botrytis spp.*, *Alternaria spp.*, *Rhizoctonia spp.*, and other leaf-spotting fungi on many ornamentals.

Fenarimol (Rubigan) is a systemic fungicide used for prevention or eradication of powdery mildew on roses and field and container-grown ornamentals.

Fixed copper is a general purpose fungicide and bactericide most often used as protectant against various leaf spots, *Botrytis spp.*, and anthracnose. Overall growth of some plants may be reduced by this material; follow label directions carefully to reduce the risk of phytotoxicity.

Lime sulfur (Orthorix) is a powdery mildew eradicant. Apply this material with caution when temperatures exceed 85° F.

Mancozeb (Dithane) is a dithiocarbamate fungicide used to protect against leaf spots, Botrytis, rusts, and blight. It is not systemic so thorough coverage is important for control.

Myclobutanil (Systhane) is a systemic fungicide applied as a foliar spray that is both a protectant and eradicant of rusts and of powdery mildew of carnations, crepe myrtle, gerbera, roses, and snapdragons. It also controls Cercospora leaf spot.

Neem oil (Triact) is a broad-spectrum botanical pesticide derived from the neem tree that is effective against various fungal diseases including black spot on roses, powdery mildew, downy mildew, anthracnose, rust, and leaf spot.

Piperalin (Pipron) is a foliar spray that eradicates powdery mildew on rose, lilac, dahlia, phlox, zinnia, chrysanthemum, and catalpa.

Potassium bicarbonate (Kaligreen) can be used to eradicate powdery mildew infections on roses. Because it is a contact-type fungicide, thorough coverage is essential for good control.

Propiconazole (Banner Maxx) is a preventative fungicide against powdery mildews, rusts, leaf spots, and blights.

Stylet oil (JMS Stylet Oil) is available to control black spot and powdery mildew on roses, poinsettia, chrysanthemum, diffenbachia, and philodendron. There have been some phytotoxicity problems with this material, especially on greenhouse roses.

Triadimefon (Strike) is a long-lasting systemic fungicide used for control of powdery mildews, rusts, and leaf blight and spots in greenhouses and commercial nurseries.

Triforine (Funginex) is a systemic fungicide for control of powdery mildew, black spot, and rust of rose. Also effective for rust on aster.

Vinclozolin (Vorlan) is used in outdoor settings as a foliar spray or in a thermal fogger to protect against *Botrytis* and *Sclerotinia* spp.

Wettable sulfur can be used as a spray to protect ornamentals against powdery mildew. It has no eradication action and it leaves a residue on plants that could cause plant injury. Apply this material with caution when temperatures exceed 85° F.

General information for SOIL FUNGICIDES
(Reprinted from: Grebus et al. 1998)

Soil Fungicides. Some fungicides work best if incorporated before planting. Others may be incorporated or applied after sowing or planting. Some soil fungicides control a narrow range of organisms while others control a wide range of organisms. Some of the narrow range chemicals are the most effective in controlling a specific organism. Combinations are used to increase the number of organisms controlled.

Fosetyl-Al (Aliette) is active against *Phytophthora* species and some *Pythium* species. It is applied as a soil drench or as a foliar spray. It is absorbed by foliage and moves into roots. It is used as a drench at 0.8 to 1.6 lb a.i./1000 sq ft using 0.5 to 1.5 pt/sq ft. As a foliar spray it is applied at 2 to 4 lb a.i./100 gal water.

Iprodione (Chipco 26019) is used at 0.2 lb a.i./100 gal water applied as a drench (1-2 pt/sq ft) at seeding or transplanting. It is effective against *Rhizoctonia* damping-off and gray mold. Has moderate effectiveness against *Thielavopsis* spp. and *Fusarium*. Some iprodione is absorbed by plant parts.

Mefenoxam (Subdue Maxx) is active against *Pythium* and *Phytophthora* fungi and downy mildews. This material replaces the product metalaxyl (Subdue). It is applied at planting as a drench and periodically thereafter as needed. Mefenoxam is also available in a granular formulation to use before planting. It is water soluble and readily leached from soil. It is absorbed by plant parts including roots; movement in the plant is *primarily in the xylem.*

PCNB, also called quintozene, is very active against diseases caused by *Rhizoctonia solani* and *Sclerotinia* spp. and is the best available fungicide for southern wilt caused by *Sclerotium rolfsii*. It is insoluble in water and must be thoroughly mixed with soil to reach its desired depth of control. It works through vapor action and has good residual action. It is inactive against Pythium fungi. It is used at 0.5 to 1 lb a.i./1000 sq ft and mixed into the top 2 inches of soil for control of *Rhizoctonia* damping-off. Germination of some seeds may be inhibited and small plants may be stunted by this fungicide.

Streptomyces griseoviridis (Mycostop) is a biofungicide used to control seed rot, root and stem rot, and wilt caused by *Fusarium*, *Alternaria*, and *Phomopsis* in container-grown ornamentals. In the greenhouse is suppresses Botrytis gray molds and root rots of *Pythium*, *Phytophthora*, and *Rhizoctonia*.

Thiophanate-methyl (FungoFlo, Clearys 3336, Domain FL) is generally applied after sowing. It helps to control gray mold, *Rhizoctonia* diseases, cottony rot, *Thielaviopsis* rots, and some *Cylindrocladium diseases. It is not effective against pythiaceous fungi such as Pythium* spp., *Phytophthora* spp., *Sclerotium rolfsii*, *Botrytis* spp., and *Fusarium* spp. It is used at 0.5 lb a.i. or less/100 gal water and applied as a drench or heavy spray (1-2 pt/sq ft). Thiophanate-methyl is absorbed by plant parts exposed to the chemical. Roots may absorb the fungicide (or its breakdown product carbendazim), which moves in the xylem to transpiring leaves.

Trichoderma spp. (BioTrek) is a biological fungicide for control of root diseases caused by *Pythium*, *Rhizoctonia*, and *Fusarium* in nursery and greenhouse crops. It is formulated as a seed protectant, a soil drench, and as granules.

Trifumizole (TerraGuard) is a protectant fungicide used as a cutting soak, soil drench, foliar spray, or through chemigation for control of *Cylindrocladium* spp., powdery mildews, leaf spots, and scab. Its use is restricted to enclosed commercial structures such as greenhouses and shade houses.

Vinclozolin (Vorlan) is effective for control of *Botrytis* spp. and *Sclerotinia* spp. on ornamental herbaceous, woody, and bulb crops grown in greenhouses.

Seed Treatments. Streptomyces griseoviridis (Mycostop) is used as a seed treatment for damping-off and early root rots for ornamentals planted in fields or greenhouse. Captan and thiram are also seed treatments; they are generally applied at rates of 1 to 4 oz/100 lb seed, but they offer only a small margin of protection.

Vertebrate/Snail Control

Growers were asked to list any vertebrate pests that were problems. Squirrels were the most common problem. Other animals were birds, gophers, raccoons, rabbits, and rats/mice. Snail control is also important. In 1997, 7244 pounds of metaldehyde was applied in the top 5 nursery production counties (CDPR PUR, 1997).

Brown garden snail (*Helix aspersa*)
(Ohlendorf and Flint, 1999)

Description: Snails are mollusks and move along the ground along on a muscular appendage that secretes mucus to facilitate movement. Brown garden snails are hermaphroditic, thus they are able to fertilize their own eggs. Adult brown garden snails lays its eggs into the soil. Nearly 100 eggs are laid at a time and they may lay eggs up to six times a year. Snails mature in about 2 years. Snails are most active during the night. They retreat to dark, moist areas during the day.

Damage: Snails feed on a variety of living plants by scraping the leaves with their rasp-like mouthparts. They can chew irregular holes in leaves and can clip off smaller, succulent plants.

Biological control: The most common biological control for the brown garden snail is a predaceous snail, the decollate snail (*Rumina decollata*). Although it feeds only on small snails, it is an effective method of control in areas where it can be used (Fresno, Imperial, Kern, Los Angeles, Madera, Orange, Riverside, Santa Barbara, San Bernardino, San Diego, Ventura, and Tulare counties).

Cultural control: Elimination of areas for snails to hide during the day is nearly impossible in a nursery. Snails can hide under containers, in the canopy of plants, or under mulch. In small areas, handpicking can remove many snails but this must be done on a consistent basis. Likewise, placing boards or other material out as shelter can trap snails. The accumulated snails can then be scraped off and destroyed. Copper foil barriers can be effective to keep snails from crawling into pots but each pot must have a band encircling it.

Chemical control: Snails can be controlled using baits. Metaldehyde baits are the most commonly used type. Iron phosphate is a relatively new control material with very low toxicity but cost the material is greater than that of metaldehyde so it has not yet been widely accepted.

OVERARCHING CHALLENGES TO IMPLEMENTING CHANGE

- Large diversity of plant species produced
- High value crops
- Low tolerance for aesthetic damage
- Requires high levels of pest management
- Few economic thresholds available for pests
- Short re-entry intervals required to allow handling
- Strong likelihood that some pest species will be come resistant
- Shipping and quarantine regulations for pest species
- Mandatory requirement for fire ant control in quarantine areas
- Social and legal concerns with ag-urban interface

INNOVATIONS

- Modify application methods for fire ant control to reduce amount of materials used and worker exposure.
  -improve monitoring techniques
  -use of bait materials

- Increase use of monitoring and scouting techniques to:
  -detect the presence of pest problems early
  -select best materials for the pests that are present
  -time applications to susceptible life stages
  -direct pesticide application to affected areas

- Use of reduced risk materials and new chemistries (e.g. substitutes for organophosphates and carbamates).

- Improve irrigation management techniques to reduce pesticide and fertilizer run off.

- Optimize timing of applications and select best fertilizer formulations to nitrate levels in runoff.

- Use of border strips or holding ponds to reduce pesticide runoff.

- Use of biologicals for disease and insect management.

- Use of mulches for weed control.

Specific Aspects of Challenges and Innovations

Alternatives to Organophosphates and Carbamates

Ant Control in Nurseries

Challenges to change: Under current fire ant quarantine procedures, an entire nursery must be treated if even a single fire ant is found. The treatment protocol includes broadcast of either an ant bait or a pyrethroid such as bifenthrin. Thus, hundreds of acres are treated even when the infestation may be local. In addition, pesticides such as bifenthrin or chlorpyrifos are incorporated into each pot's soil. Nurseries estimate the cost of fire ant treatments at $1-2,000/acre. There are obviously hazards associated with these practices. Applicators need to wear protective clothing during the application. Nurseries are constantly watering their plants and chlorpyrifos and bifenthrin have been detected in the runoff by the Department of Pesticide Regulation. These pesticides pose a hazard to fresh water organisms and are also implicated in law suits pertaining to their running into coastal bays. There is a disparity between the amount of pesticide used and the size of the infestation. Current practices make no distinction between an isolated find of fire ants and a generalized infestation. Thus, all treatments are based on worst-case scenarios.

IPM innovation: Our response to the above challenge is with improved monitoring and selective treatment of fire ants. Our concept is to use sugar water as an attractant to find where the ants are active. We have found that sugar water is as effective as the Spam bait currently in use. We put the sugar water into graduated plastic tubes. We can then either weigh the tubes or read the volume directly to determine how much has been consumed by the ants. By knowing how much sugar water is consumed over 24 hrs, we can infer the size of the ant population because the number of ant visits is correlated with the amount taken. Once we have found where the fire ants are located, we replace the sugar water monitors with containerized ant baits. We are only putting out toxicants where we find ants. Furthermore, our baits are in stations that the ants enter. This approach avoids direct contact of pesticide with the ground and should alleviate runoff problems. *We will conduct water runoff studies to show that the use of* bait stations avoids pesticide runoff problems.

Fire ant pheromones may be useful for bait enhancement. For example, the brood pheromone *causes ants to pick up objects and bring them into the nest.* We will see whether these chemicals can be used in connection with containerized baits to increase the efficiency of these devices.

Challenges to change: Replace organophoshpates and other pesticides with organic repellents.

IPM innovation: Theoretically, repellents could be incorporated into potting soil in place of pesticides. There are a number of EPA de-regulated products that could serve as repellents. These include orange peel extract and oils such as mint oil. If we can demonstrate that ants will not enter potted plants with these materials in the soil, we might be able to avoid the need for soil incorporation of pesticides. This approach would again avoid the risk of worker pesticide contact and runoff problems. It would also avoid the costs associated with the soil incorporation of pesticides.

Challenges to change: Current fire ant monitoring techniques are inefficient and expensive to implement.

IPM innovation: We want to replace the current method of ant baiting with Spam to other less expensive and more efficient techniques. Other materials such as cat food, potato chips, tuna fish, and sugar water may be more efficient than Spam. For example, a trail of potato chips on the ground, applied with a shaker bottle, may be more efficient and less expensive than the Spam. We will use baits that are more selective for fire ants.

WORKER EXPOSURE

Pesticide use practices, environmental fate, and occupational exposure

Challenges to change: Determination of occupational risk from chemical technologies in IPM will be based upon an initial inventory of presumed work practices and an estimate of chemical risk factors associated with actual work practices and chemical exposure. This inventory will involve environmental chemical analysis, video taping of critical work practices, workplace (environmental) monitoring of chemical residues which may result in human exposure or be transported to the environment, and biological monitoring of groups of workers who perform work of particular relevance to risk management.

IPM Innovation: In order to conduct meaningful risk reduction activities we will acquire a tiered set of worker exposure data. Tier 1 will represent the current U.S. EPA chemical exposure estimate based upon published default values for time and residue accumulation. Tier 2 projections will be developed using actual work practice information and hypothetical reduced risk management practices that become apparent. Tier 3 projections will represent biological monitoring of the chemical exposures of existing and alternative work practices. This will include activities related to mixing/loading/applying as well as cultural practices which may result in exposures of workers or the public to applied surface chemical residues. The baseline will be set by the Tier 1 evaluation and the ultimate assessment of risk reduction will be determined by the (Tier 1 - Tier 3) exposure.

Environmental fate and transport will be a second consideration as it relates to the fate and transport of chemical residues which may result in human exposure or environmental release. We will identify sinks which may be secondary sources of exposure to chemicals used in IPM. These sinks (soil, other bedding materials, equipment, building materials) may offer significant opportunities for exposure remediation. Restated, sources of exposure will be minimized to obtain the effective and efficient use of chemical technologies coupled with other advanced agricultural practices.

Protection of Surface and Groundwater

Problem: The nursery industry is being targeted as a point source of pesticide pollution by Regional Water Quality Control Boards because of the Clean Water Act and the TMDL process that is being implemented statewide. Monthly CDPR monitoring of runoff from nurseries that are regulated and permitted for pesticide application have detected organophosphates, carbamates, synthetic pyrethroids, and other pesticides. This situation will be exacerbated in March 2000 when CDFA implements the compliance program for the Glassy Winged Sharpshooter. This will require that nursery stock be free of Glassy Winged Sharpshooter and that nurseries begin a monitoring and treatment program for this pest. Nurseries throughout the state will be faced with these or similar challenges.

Challenges:

How to prevent the off site movement of pesticides from nurseries that are required to apply them.

Challenges to Change:
Because nurseries are required to apply pesticides in order to meet the requirements of the compliance agreements for quarantine pests, any chance of making a major impact on pesticide use through traditional IPM techniques such as monitoring, cultural, physical, mechanical, and biological control strategies is dramatically reduced.

Innovations to Mitigate Runoff:
Runoff mitigation can be achieved through an integration of industry practices currently being utilized by various agricultural commodities. These would include water recapture systems, drip irrigation, subirrigation, ebb and flood irrigation, computerized irrigation, and pulsed irrigation technologies. The use of soil moisture sensing devices, CIMIS and Eto, and irrigation auditing and efficiency would assist in mitigating this problem.

Other practices would be the use of nonvegetative and vegetative buffer strips, sediment basins, and polymers to flocculate sediments from water and the use of non-permeable membranes under the containers to direct water into holding ponds or to areas where the water can be used for subirrigation.

Various groups throughout the state are developing educational materials and expertise to deal with mitigation of pesticide runoff. We have already contacted several groups and plan to integrate their materials into our training programs and demonstrations.

Demonstration of Innovations:
Several Pest Management Alliance nurseries have agreed to apply some or all of these technologies and demonstrate them to other growers at sponsored tours. In addition, UC DANR has several field stations where some of these technologies either exist or can be setup for demonstration during tours or workshops.

Challenges to Change: Preventative use of herbicides is less expensive than hand-weeding after weeds have emerged. Broadcast application of granular herbicides is used to control weeds in the containers and between the containers but herbicide loss from surface runoff can impact waterways.

IPM Innovation: Use of mulches to limit weed germination. Adapt subirrigation or subsurface irrigation techniques for certain size containers. Identify source of weeds introduction or re-introduction

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APPENDICES

List of pesticides used for
insects/mites
weeds
plant diseases

Grower survey

Insect and Mite Control Materials (RIFA control discussed in body of report)

Class	Trade Name	Common Name	Signal Word	Manufacturer	A	W	M	S	T	L	W	SM	Notes
Biological	BotaniGard 22WP	*Beauveria bassiana*	caution	Mycotech	X	X	X		X				Treat every 7 days while insects are active. Do not tank mix with most fungicides.
biological	BotaniGard ES	*Beauveria bassiana*	warning	Mycotech	X	X	X		X				Treat every 7 days while insects are active. Do not tank mix with most fungicides.
botanical	Cinnacure/ Cinnamite	cinna-maldehyde	caution	Progard/ Mycotech					X			X	Use product within 10 days of breaking seal.
carbamate	Carbaryl 13 registered materials	Carbaryl	caution, warning	7 manufacturers							X		
carbamate	Mesurol 75 W	methiocarb	warning	Gowan	X				X			X	
carboximide	Hexygon	hexythiazox	caution	Gowan								X	
chloronicotinyl	Marathon 1% Granular	imidacloprid	caution	Olympic	X	X	X	X	X	X			Not to be used more than once every 16 weeks. Do not apply to soils that are water logged or saturated. Do not apply to bedding plants intended to be used as food crops. Thrips suppression only.
chloronicotinyl	Marathon 60 WP	imidacloprid	caution	Olympic	X	X	X	X	X	X			Not to be used more than once every 16 weeks. Do not apply to soils that are water logged or saturated. Do not apply to bedding plants intended to be used as food crops. Thrips suppression only. Apply only as a drench.
Insect growth regulator	Adept	diflubenzuron	caution	Uniroyl		X					X		Whitefly suppression. Apply as spray or drench to top 2" of soil. Also effective on fungus gnat larvae and lepidopteran larvae.
Insect growth regulator	Azatin XL Plus	azadirachtin-neem extract	caution	Olympic	X	X	X		X	X	X		Must contact insect. Repeated applications necessary. Aphid suppression only. On fungus gnats, only effective on larvae. Label permits low volume application.

A=aphids M=mealybugs T=thrips SM=spider mites
W=whiteflies S=scales L=leafminers W=worms

Class	Trade Name	Common Name	Signal Word	Manufacturer	A	W	M	S	T	L	W	SM	Notes
Insect growth regulator	Citation	cyromazine	caution	Novartis						X			Certification training required to use this product. Also effective against fungus gnat and shore fly larvae.
Insect growth regulator	Distance	pyriproxyfen	caution	Valent		X		X					Do not apply more than 2 times per cropping cycle of per 6 months.
Insect growth regulator	Enstar II	s-kinoprene	warning	Wellmark	X	X	X	X					Apply pre-bloom. On mealybugs, only effective on immatures.
Insect growth regulator	Ornazin	azadirachtin-neem extract	caution	Amvac	X	X	X		X	X	X		
Insect growth regulator	Pyrigro	pyriproxyfen	caution	Whitmire Microgen		X		X					Do not apply more than 2 times per cropping cycle of per 6 months.
Macrocyclic lactone	Avid 0.15EC	abamectin	warning	Novartis					X	X		X	Label permits low volume application.
Microbial	Dipel 2X	*Bacillus thuringienses*, subs. Kurstaki	caution	Abbott Labs							X		Most effective against early instar larvae; Pheromone trapping recommended for timing applications.
Microbial	Dipel DF	*Bacillus thuringienses*, subs. Kurstaki	caution	Abbott Labs							X		Most effective against early instar larvae; Pheromone trapping recommended for timing applications.
Microbial	XenTari	*Bacillus thuringienses*, subs. Aizawai	caution	Abbott Labs							X		Most effective against early instar larvae; Pheromone trapping recommended for timing applications.
Microbial	Mattch	*Bacillus thuringienses*, endotoxin	caution	Mycogen							X		Most effective against early instar larvae; Pheromone trapping recommended for timing applications.
Nicotine	Fulex Nicotine	nicotine	danger	Fuller System					X				
Oil	Sunspray Ultra-Fine Spray Oil	paraffinic oil	caution	Sun Corp.	X	X	X	X				X	Do not spray plants under stress. Target pest must be completely covered with spray. Check label for list of plants that can be treated. May cause injury to flowers.

Class	Trade Name	Common Name	Signal Word	Manufacturer	A	W	M	S	T	L	W	SM	Notes
Oil	Triact 90 EC	clarified hydrophobic extract of neem oil	caution	Thermo Trilogy Corp	X	X	X	X	X			X	Do not spray plants under stress. Target pest must be completely covered with spray. Check label for list of plants that can be treated. May cause injury to flowers. Difficult to get coverage in flowers, best for thrips on foliage.
Organochlorine	Endosulfan 50 WP	endosulfan	danger	Gowan	X	X		X	X			X	Check local water/runoff restrictions.
Organochlorine	Endosulfan 3EC	endosulfan	danger	Gowan	X	X		X	X			X	Check local water/runoff restrictions
Organochlorine	Endosulfan 50 WSP	endosulfan	danger	Gowan	X	X		X	X			X	Check local water/runoff restrictions.
Organochlorine	Kelthane	dicofol	caution	Rohm & Haas								X	
Organophosphate	Many	diazinon	caution	many		X	X	X	X	X		X	Will not control whitefly, only suppress. Check label for plants exhibiting phytotoxic reaction.
Organophosphate	Orthene T, T & O Spray	acephate	caution	Valent	X	X	X	X	X	X*	X		
Organophosphate	Pinpoint	acephate	caution	Valent	X		X	X			X		To control labeled insects in smaller pots with lower rates. (Not labeled for greenhouse use.)

Class	Trade Name	Common Name	Signal Word	Manufacturer	A	W	M	S	T	L	W	SM	Notes
Organophosphate	PT 1300 Orthene TR	acephate	warning	Whitmire Microgen	X		X	X	X	X	X		
Organophosphate	Plantfume 103	sulfotep	danger	Plant Products Corp.	X	X	X	X	X			X	
Organophosphate	PT Duragard 1325 ME	chlorpyrifos	caution	Whitmire Microgen	X	X	X	X	X	X	X		
Organophosphate	various	malathion	caution	various		X		X					
Organophosphate	various	dimethoate	warning	various		X		X					
Organophosphate/ synthetic pyrethroid	PT Duraplex TR	chloropyrifos cyfluthrin	warning	Whitmire Microgen	X	X	X		X		X		
Pyridazinone	Sanmite	pyridaben	danger	BASF		X						X	Use at least two different chemical between application of Sanmite. Do *not use fertilizers containing Boron.*
Pyridine azonethines	Endeavor	pymetrozine	caution	Novartis	X	X							Starves insect so no immediate knockdown, but will cause insect to cease feeding.
Soap	40 % Insecticidal Soap	potash soap	caution	Micro-Flo	X	X			X			X	
Soap	Insecticial Soap	potash soap	warning	Olympic	X	X			X			X	
Soap	Safer	potash soap	warning	Safer	X	X						X	
Spinosyn	Conserve SC	spinosad	caution	Dow Agro- sciences					X	X	X	X	Do not apply more than 10 times in a 12 month period. Do not apply to vegetables. Do not apply more than three times in a row without rotating to a different chemistry. Compatible with most beneficials, but highly toxic to bees. Mixed results on Spider mites (see label).
synthetic pyrethroid	Astro	permethrin	caution	FMC	X	X	X			X			Direct application to blooms may cause browning of petals. Marginal leaf burn may occur on salvia. Label permits low volume application.

Class	Trade Name	Common Name	Signal Word	Manufacturer	A	W	M	S	T	L	F	W	SM	Notes
Synthetic pyrethroid	Attain	bifenthrin	danger	Whitmire								X		Check label.
Synthetic pyrethroid	Decathlon 20 WP	cyfluthrin	caution	Olympic	X	X	X	X			X	X		Label permits low volume application. Also effective against fungus gnat adults.
Synthetic pyrethroid	Mavrik Aquaflow	fluvalinate	caution	Wellmark	X	X	X	X			X	X	X	Label permits low volume application. Also effective against fungus gnat adults.
Synthetic pyrethroid	PT 1100 Pyrethrum TR	pyrethrin + PBO	caution	Whitmire Microgen	X	X	X	X	X		X	X		Synthetic pyrethroids sometimes used as an irritant when mixed with other pesticides. Also effective against fungus gnat adults.
Synthetic pyrethroid	Pyrenone Crop Spray	pyrethrin + PBO	caution	Agroevo Environmental Health	X	X	X		X		X	X		Synthetic pyrethroids sometimes used as an irritant when mixed with other pesticides. Label permits low volume application. Also effective against fungus gnat adults.
Synthetic pyrethroid	Talstar GH	bifenthrin	caution	Whitmire Microgen	X	X	X				X	X	X	Label permits low volume application. Also effective against fungus gnat adults.
Synthetic pyrethroid	Talstar Nursery Flowable	bifenthrin	caution	Whitmire Microgen	X	X	X				X	X	X	Label permits low volume application. Also effective against fungus gnat adults.
synthetic A25pyrethroid	Tame 2.4 EC Spray	fenpropathrin	caution	Valent	X	X	X				X	X	X	Label permits low volume application. Also effective against fungus gnat adults.
synthetic pyrethroid + botanical	Pyrellin EC	rotenone + pyrethrin	caution	Webb Wright	X	X	X		X		X	X		Synthetic pyrethroids sometimes used as an irritant when mixed with other pesticides. Also effective against fungus gnat adults.

Weed Control Materials

Common preemergent herbicides labeled for use in nurseries.

Common name	Rate	Trade name	REI (hr)
Prodiamine	1-2.3lb/A (Factor),	Factor, RegalKade	12
Diclobenil	100 lb/A	Casoron 4G, others	12
DCPA	7-8 qt/A	Dacthal Flowable	12
Napropamide	200-300 lb/A	Devrinol	
Dithiopyr	2 qt/A	Dimension	12
Isoxaben	0.66-1.33 lb/A	Gallery	12
Oxyfluorfen	2-8 pt/A	Goal 2XL	24
Oxyfluorfen + pendimethalin	100 lb/A	Ornamental Herbicide 2	24
Pendimethalin	2.4-4.8 qt/A(EC), 3.3-6.6 lb/A(WDG), 74-114 lb/A (SWC)	Pendulum 3.3 EC, Pendulum WDG, Southern Weedgrass Control	12
Metolachlor	2-4 pt/A	Pennant	24
Simazine	2-3 qt/A	Princep	12
Oxadiazon	100-200 lb/A (G), 4-6 lb/A (WSP)	Ronstar G, Ronstar WSP	12
Oxyfluorfen + oryzalin	100 lb/A	Rout	24
Oryzalin	2-4 qt/A	Surflan	12
Oxyfluorfen + oxadiazon		Regal O-O	24
Trifluralin + isoxaben	100-200 lb/A	Snapshot	12
Trifluralin + oryzalin	100 lb/A	XL2G	12

Postemergent herbicides labeled for use in nurseries (not over-the-top).

Common name	Rate	Trade name	REI (hr)
Fluazifop-p-butyl	0.6%	Fusilade II	12
Halsulfuron	0.66-1.33 oz/A	Manage	12
Diquat	1-2 pt/A or 0.25-0.5%	Reward	24
Glyphosate	0.5-10% (Pro), 1oz/gal (drypak)	Roundup Pro, Roundup Drypak	4
Potassium salts of fatty acids		Scythe	

Plant Disease Control Materials

Common materials used for plant disease control. Since there are over 200 materials registered for disease control in ornamentals. to simplify the information, different formations of the same active ingredient are not listed.

Trade Name	Common Name	Class
GALLEX	2,4-XYLENOL + META-CRESOL	"Biological"
CINNACURE, CINNAMITE	Cinnanaldehyde	"Biological"
FORTUNE AZA	HYDROGEN CYANAMIDE	"Biological"
NEEM OIL , TRIACT	Neem oil	"Biological"
M-PEDE INSECTICIDE/FUNGICIDE	POTASH SOAP	"Biological"
QUELL , SUBDUE MAXX	Mefenoxam	Acylalanine
BOTRAN	DICLORAN	Aromatic hydrocarbon
ENGAGE, PCNB,TERRACHLOR, TURFCIDE	PCNB	Aromatic hydrocarbon
CAVALIER , CLEARYS 3336	Thiophanate-methyl	Benzimidazole
DOMAIN	THIOPHANATE-METHYL	Benzimidazole
FUNGO,FUNGO FLO,SYSTEC, SYSTEMIC FUNGICIDE, ZYBAN	Thiophanate-methyl	Benzimidazole
DUOSAN	THIOPHANATE-METHYL + MANCOZEB	Benzimidazole+dithiocarbamate
DACONIL, BRAVO, COUNTDOWN,ECHO, FUNG-ONIL, SUPINIL	Chlorothalonil	Benzonitrile
GALLTROL-A, NORBAC-84-C	AGROBACTERIUM RADIOBACTER	Biological
AQ10 BIOFUNGICIDE	AMPELOMYCES QUISQUALIS	Biological
MYCOSTOP BIOFUNGICIDE	STREPTOMYCES GRISEOVIRIDIS	Biological
AGRI-MYCIN	STREPTOMYCIN SULFATE	Biological
HERITAGE	AZOXYSTROBIN	Biological (Strobilurin)
BIO-TREK, T-22, ROOTSHIELD	TRICHODERMA HARZIANUM	Biological
OXINE	CHLORINE DIOXIDE	Chlorine
TRI-CLOR	SODIUM HYPOCHLORITE	Chlorine
NUTRA-SPRAY COPOPHOS	Copper	Copper
BLUE SHIELD,CHAMP,BAC-STOP,COPPER FLOWABLE,KOCIDE,KOP-HYDROXIDE,NU-COP	COPPER HYDROXIDE	Copper
COPPER SOAP	COPPER OCTANOATE	Copper
CLEAN CROP C-O-C-S	COPPER OXYCHLORIDE SULFATE + SULFUR	Copper+Sulfur
CHIPCO 26019 BRAND FUNGICIDE	Iprodione	Dicarboximide
CURALAN, ORNALIN,VORLAN	Vinclozolin	Dicarboximide

PIPRON	Piperalin	Dichlorobenzoate
DITHANE,FORE,FORMEC,MANZATE,PENNCOZEB, PROTECT	Mancozeb	Dithiocarbamate
MANKOCIDE FUNGICIDE/BACTERICIDE	MANCOZEB+copper hydroide	Dithiocarbamate + copper
CAMELOT, PHYTON-27	Copper sulfate	Fixed copper
ALIETTE	Organic phosphate	Fosetyl-Al
DECREE	Fenhexamid	Hydroxyanilide
TERRAGUARD	Triflumizole	Imidazole
ORNAZIN	AZADIRACHTIN	Neem oil extract
JMS STYLET-OIL,SUNSPRAY	PETROLEUM DISTILLATES	Oil
CAPTAN	Captan	Phtalimide
RUBIGAN	Fenarimol	Pyrimidine
PHYSAN 20	DIMETHYLETHYLBENZYL AMMONIUM CHLORIDE	Quartenary ammonia
LIME SULFUR SPRAY	Lime sulfur	Sulfur
GOLDEN-DEW, STIRRUP MYLOX, THIOBEN	Sulfur	Sulfur
ZIRAM	Ziram	Thiocarbamate
EAGLE, SYSTHANE	Myclobutanil	Triazole
BANNER MAXX , PPZ	Propiconazole	Triazole
THIRAM	Thiram	Triazole
BAYLETON,FUNGI-FIGHTER, STRIKE	TRIADIMEFON	Triazole
TRIFORINE	Triforine	Triazole

Fumigants

CHLOROPICRIN
METAM SODIUM
METHYL BROMIDE
TELONE C-15
TERR-O-GAS 75

Please provide the following information to the best of your knowledge.

All information provided will be kept confidential and is used for research purposes only.

1. In which county or counties is your nursery located?________________________

2. What is the size of your production area?
   - <10A ____
   - 10-30A ____
   - 31-50A ____
   - 51-100A ____
   - >100A ____

3. What are you approximate costs and/or man-hours for the following (please indicate if the amounts are per year or per month):
   - a) Scouting______________________
   - b) Application of pesticides (labor and equipment) ______________________
   - c) Pesticide________________________

4. On the attached pages, please provide information as indicated regarding specific pest classes (insects and mites, diseases, weeds). For non-pesticide controls indicate what other practices you are using (handweeding, biocontrols, changing irrigation methods, etc.)

5. What other pest or pesticide issues are important to you?

exotic pests(please specify) ____________________________________

pesticide runoff (please specify) ____________________________________

ag-urban issues (please specify) ____________________________________

other (please specify) ____________________________________

6. Other pests?
   - Birds__
   - Squirrels__
   - Gophers__
   - Other (please specify) ____________________________________

7. Please rate each of the factors listed below according to how much they impact your pest control issues.
   1 =none 2=very minor, 3= minor, 4=somewhat important, 5=very important

	1	2	3	4	5
Labor availability					
Labor cost					
Pesticide availability					
Pesticide cost					
Environmental regulations					
Pesticide and fertilizer runoff					
Water recycling					
Scheduling of pesticide application					
Availability of low risk pesticides					
Training or education regarding pests, pesticides, integrated pest management					

Pest Control in Container Nurseries: Top Insect pests

Pest	Rank all pests listed from most pesticide used (1) to least amount of pesticide used (12 or more) to control this pest.	Primary pesticides used for this pest	Other method of control used
Fire Ants			
Other Ants- (Argentine Ant)			
Mites			
Aphids			
Whiteflies			
Scales			
Mealybugs			
Caterpillars			
Borers			
Thrips			
Fungus Gnats			
Leaf Miners			
Other:			

Pest Control in Container Nurseries: Top Weeds

Pest	Rank all pests listed from most pesticide used (1) to least amount of pesticide used (12 or more) to control this pest.	Primary pesticides used for this pest	Other method of control used
Common groundsel			
Bittercress			
Oxalis (woodsorrel)			
Prostrate spurge			
Fireweed			
Cudweed			
Poa annua			
Liverwort			
Pealrwort			
Chickweed			
Other:			